TEACHING SCIENCE
IN
OUR SCHOOLS

by

C. P. S. NAIR, M.A., M.Ed.
Farook Training College,
Calicut

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To

Sreeja

my daughter

PREFACE

A comparative study of our traditional and immediate pasts would bring to lime-light the fact, that the decay of our nation begins with our neglect of science. It was only after the attainment of independence that we were convinced of this, thanks to the efforts of our late Prime Minister, Shri Jawaharlal Nehru, whose ever-cherished ambition was the creation of a modern scientific society. But when we were very conveniently sleeping, other nations of the world have gone much ahead and now we have to double up our speed so that we can at least be in their vicinity. This can be possible only through a properly planned science education.

A deep peep into the science education in India reveals that the faults are more in the methods of teachers than on the matter taught. Many of our science teachers are trained and qualified for teaching science. But still the indisputable fact remains that science is badly taught and poorly learned. Even most of the qualified teachers do not teach science in the way it should be taught, not to speak of the many who are not qualified. At the college level science teachers still continue to show criminal negligence towards the methods of teaching.

This book is an humble attempt on my part to contribute something to the area of teaching science. The book has been divided into three parts, why science, what science, and how science. Anyhow it is not an exhaustive treatment and it is expected only to act as an inducement for science teachers and students of teaching science to go ahead with the subject. The book covers in a general way the B. Ed. syllabus (for Teaching Physical Science, Teaching Natural Science and Teaching General Science) prescribed by the various Universities in India and it is hoped that it will be of good use to our student teachers at various levels.

I am extremely grateful to all my colleagues and friends especially to Mr. T. Balakrishnan whose constant encouragement is behind the publication of this book.

My immense thanks are also to M/s S. Chand & Co. (Pvt.) Ltd., Ram Nagar, New Delhi-55 for undertaking the publication of this book and doing the job so neatly and impressively.

I entrust the book in the hands of the science teachers of India whose role is vital in the building of a new, modern, scientific society in our still remaining traditional conservative India.

Farook College P.O.
1-11-1971

C.P.S. NAIR

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SECTION I

WHY SCIENCE ?

CHAPTER I

THE MEANING AND IMPORTANCE OF SCIENCE

Defining Science

It is only appropriate that a discussion on teaching science starts with definition of science. What is Science ? Even scholars of science give only a partial definition of the subject. There are as many definitions as there are people who have tried to define the subject. Einstein defines science as, 'the attempt to make the chaotic diversity of our sense experience correspond to a logically uniform system of thought.'[1] The Columbia Encyclopaedia defines science as, "an accumulated and systematised learning in general usage restricted to natural phenomena. The progress of science is marked not only by an accumulation of fact, but by the emergence of scientific method and of the scientific attitude"[2]. According to John Woodburn and Ellsworth S. Obourn[3], "Science is that human endeavour that seeks to describe with ever increasing accuracy the events and circumstances that occur or exist within our natural environment". The Science man power project considers science "as a cumulative and endless series of empirical observations which result in the formulation of concepts and theories, with both concepts and theories being subject to modification in the light of further empirical observations. Science is both a body of knowledge and the process of acquiring and refining knowledge.'"[4]

The analysis of these definitions or any accepted standard definition of science reveals the two aspects of science—science as a product and science as a process. The whole of accumulated facts, concepts, principles, hypotheses, theories, etc., come under the product of science whereas scientific mindedness comes under the process of science. Scientific mindedness includes the scientific methods, attitude, interest and appreciation.

A teaching of science will do full justice to the subject only if it covers these two broad areas of science. There was a time when science as a school subject was taught as a product alone, but in the later half of the 20th century, there is a shift in emphasis to science as a process.

Importance of Science

Science as a subject in any curriculum has certain unique advantages. If science has overthrown the conservative elements which tried to bar its entry into the curriculum, it is because of these advantages. The position and importance of science in this century cannot be overemphasised. Nations that have neglected it in the past have already paid the penalty for it, by getting themselves immersed in poverty and backwardness. These countries lag behind in social mobility and social progress.

The need of science education becomes all the more important in Asia and especially so in the Indian context. Tracing the history of India, we find that the country though highly philosophical and religious in the traditional past, did not abandon science. On the contrary, science and technology had advanced very much in ancient India. Ancient documents reveal that the science of medicine, metallurgy, Astronomy and Mathematics were highly developed here. The chemistry behind the Ajanta paintings and the famous non-rusting iron pillar near New Delhi is even now a puzzle to the scientists. The decimal place-value system and the zero-mark contributed by India formed the very basis for further progress in all fields of science. "The importance of the creation of the zero-mark can never be exaggerated. This giving to airy nothing, not merely a local habitation and a name, a picture, a symbol, but helpful power, is the characteristic of the Hindu race from whence it sprang. It is like coining the Nirvana in to dynamos. No single mathematical creation has been more potent for the general on-go of intelligence and power."[5]

It was only during the immediate past that we neglected science and scientific research. The decay of Indian science roughly begins by the 15th century. The political confusion

created and maintained by foreign invasions, internal troubles and the disinterest shown by the rulers can be said to be the general reasons for this targic decay. It is interesting to note that the decay of science marked the decay of the Indian society too.

The attainment of independence marked a change in the national science policy. The various commissions and committees appointed by the Government of Independent India have stressed the importance of science teaching. Among them the report of the Kothari Commission stands first. "The basic approach and philosophy underlying the reconstruction of education adopted by us in this report rest on our deep conviction that the progress, welfare and security of the nation depend critically on a rapid, planned and sustained growth in the quality and extent of Education and research in science and technology."[6] The Commission has suggested various practical measures for the progress and advancement of science education.

Thus tracing the history of science in the past briefly, let us come back to the topic of discussion. Why should we teach science to our pupils ? What is its added importance, if at all any, in the Indian context ?

The important aims of teaching science in India can be broadly classified under two heads (*a*) Social and (*b*) Individualistic. Ours is a democracy and the main aim of education is the development of the potentialities of the individual to the maximum extent possible for the progress and flourishing of the society. That is why we give importance for both the individual's capacities and the society's needs. With this background in the mind, let us take the two aims and discuss them in some detail.

(*a*) Social Aims. Apart from social service, education has now become a social investment. Just as we invest on industries and turn raw materials into more useful products, we invest on education, start schools and turn pupils into more sophisticated citizens fit to be active participants in an emerging social order. Assimilation, preservation, improvement and transmission of culture are the goals of any education viewed from the social point. Education is the best instrument of

social change. Therefore to mould the people along desired lines, the state has to depend on education—especially so on science education. It has its impact upon economic development, industrial progress, national advancement, etc. Science education helps the society in the following ways.

(1) *Science for scientific outlook.* The world aroud us is changing rapidly. Old beliefs are swept away and new ones take their place. "The old attitude of submission to the curses which necessarily afflicted human existence gave way to a doctrine of attack. Poverty, disease, famine, war, political tyranny, oppression and exploitation of the weak, ignorance, superstition, intolerance...existed in the world not because God willed them but because men allowed them to be. All (of these) might be greatly lessened through the use of agencies of scientific control of nature and by the application of man's intelligence and good will to the reorganisation and reconstruction of social institutions."[7] This reorganisation and reconstruction is the main task of science education. It is to change (and really changes) the traditional and conservative community of ours into a modern and progressive society. As the Kothari Commission has rightly observed, "If this change on a grand scale is to be achieved without violent revolution (and even then it would still be necessary), there is one instrument and one instrument only, that can be used—EDUCATION."[8] But any education won't serve the purpose. We have to prepare a modern, progressive curriculum for this purpose, and here science will have to be a major component.

The rank and file in India are enjoying the bliss of ignorance. Our economic backwardness and social evils are all because of this ignorance. Irrational submission to religion and spirituality produced so many superstitious beliefs. The people seriously lack scientific outlook and scientific morality. No doubt religion has induced the habit of cleanliness (like daily bath, clean clothes, keeping the house clean, etc.). But even this cannot be admired as we find in many cases the man cleaning his house, throwing all the rubbish into the neighbour's corridor.

Irrational belief in God and religion also stand in the way of national integration. Many a time, communal riots take place because of this. Religious fanatics also develop a suspicious outlook towards modern developments. The change, if at all any, is at a very low ebb. And behind the curtains of religion and caste all sorts of fissiparous tendencies flourish. All these can be wiped out through a properly organised science-oriented education.

(2) *Science for Agriculture.* More than 80% of our population live in villages and resort to agriculture as the means of their living. They are very poor and their conditions are most pitiable. Partly it is due to the revenue system and the extent of exploitation they have to suffer, but more so because of unscientific cultivation. The adoption of a science-based technology is sure to result in much improvement. In certain parts of the country scientific agriculture has already brought about the 'Green Revolution'. Yet better variety of seeds, artificial manuring, sophisticated agricultural instruments, etc., still stand as novelty to many of our farmers. A science-based education in the field of agriculture can bring about rapid and desirable changes.

(3) *Science for economic development.* "Within the last decade or so, developments in Science and Technology have shot sky high. The second industrial revolution (the age of automation) is at our door-step now and its implications stare us in the face because we do not know much about them so far as their impact on us and our society is concerned—which is lagging far behind."[9] This lagging behind was the result of the neglect of science in the past. A science-based education is the pre-requisite of economic development. Even after the completion of so many Five Year Plans, we have only reached the take-off stage. And as far the per capita income is concerned, we stand among the last four nations of the world. The life of the average man is even now miserable. The only solution for this is the rapid economic development of our nation and for this a science-based education is essential. It is what the history of U.S.A , U.S S.R. and Japan tells us. These countries first invested on education and economic development followed.

(4) *Science for modernisation.* The distinctive feature of the modern society is its affinity for science. But modernisation does not mean a refusal to recognise the importance of moral and spiritual values. On the contrary it insists on scientific morality and self-discipline. The knowledge that science and technology bring, should be balanced with the values of ethics and religion. The society in general should have scientific mindedness. This can be achieved if science is taught more as a process than as a product and necessary training in scientific thinking is provided from the very beginning.

(5) *Science for democracy.* Many qualities of heart that democratic citizens are in need of, can be induced by the teaching of Science. "A common myth has it that the scientist is a man without bias. This is non-sense. The scientist is simply a trained individual who has found a useful method of checking his bias in terms of his professional work. What he has learned a democratic people must also learn."[10] Rational thinking, mature outlook, experimental approach, co-operation, a sense of dedication to the well being of others, international feeling, impersonal judgement, etc., are common to science and democracy and in many cases for these alone. Therefore for the survival of democracy and for it to become a way of life a course in science becomes essential. India being the largest of democracies should give more prominence to the science subjects at all levels of education.

(*b*) **Individualistic.** Individual and society are the two poles of the educational system. Neglect of the one for the other would result in a lopsided educational pattern. Therefore we cannot neglect the individual solely for the cause of the society. From the individual's point, the maximum possible development of his personality is very important. Individuals vary very widely in their intelligence, capacities, and ambitions. The academic value of subjects is to be determined by measuring how far these subjects enable the individual pupils to develop their capacities to the maximum and enable them to live a successful life in this world. Thus the various branches of natural and physical sciences serve them in different ways. But

generally they come under two heads—importance of science as a product and importance of science as a process.

(1) *Science as a product to the individual.* This correspond to the importance of the quantum of scientific information at the disposal of the individual—the information at the knowledge, understanding and application levels including certain scientific skills.

Science continuously changes the physical environment in which we live. Both the subject and its benefits are universal. Within the comparatively short span of its existence, it has totally changed our world. "Science, as a dominant factor in determining the beliefs of educated man, has existed for about 300 years, as a source of economic technique for about 150 years. In this brief period it has proved itself an incredibly powerful revolutionary force. When we consider how recently it has risen to power, we find ourselves forced to believe that we are at the very beginning of its work in transforming human life. What its future effects will be is a matter of conjecture hitherto may make the conjecture a little less hazardous."[11] The main characteristic of science is its possibility of unlimited growth. Nature is inexhaustibly knowable. One new invention in some corner of the world paves the way for another thousand new inventions and discoveries and this extends as an infinite series. The 'doubling period' of science is only some ten or fifteen years now. The number of scientific books and journals increases rapidly. "The number of scientists has been doubling every ten years. Such a growth rate implies that at any given time, the number of scientists alive is nearly ninety per cent of all who ever lived since the beginning of science. So rapid is the growth of science that as some people have put it, a scientific paper is often out of date by the time it is in print, a book is out of date before the student has completed the course, a graduate is obsolescent on the day of his graduation and a research equipment is often out of fashion by the time it is procured."[12] There is knowledge explosion in all fields of science. The time gap between the basic discovery and its practical application is also only a few years now.

We live in a world of science. The comforts that science has provided for us are miraculous. It has revolutionised our whole idea about the universe. Ignorance of science is ignorance of our environment and indifference shown to it is suicidal. Without a general understanding of science, civilized life has become impossible. As Sumner has put it, "The future, therefore, can only be secure in the hands of race of people who grasp the significance of changes which scientifie discovery has brought. No statesman, sociologist or economist can afford to neglect them."[13] Many equipments that we handle, many articles that we use, many devices that are too common in our homes are the contributions of science. Many of them are so complicated and dangerous (ex :—electrical equipments, poisonous chemicals and medicines, etc.) that unskilled handling of them may bring about disastrous consequences.

Many things once supposed to be 'impossibles' are 'possibles' now. Many diseases once considered incurable can be cured very easily, thanks to the progress of medical science. Supersonic aircrafts have solved the problem of distance. Though miles apart one can take one's breakfast in Delhi, lunch at London and supper at New York now. Facilities for communication have widened largely. Even interplanetary travel and communication are now possible.

Science as a product also provides the necessary information for various hobbies which are both pastime and lucrative. Photography, soapmaking, inkmaking, improvisation of apparatus, preparation of science albums, nature study, scientific cultivation, etc., are interesting hobbies. Science provides a variety of recreational facilities too. The cinema, the radio, the television, etc., are both informative and recreative. They gradually widen the horizons of our knowledge.

Because of its immediate relevance to the life situations, the selection of the subject matter to the curriculum should be very carefully done. Subject matter relevant to the following areas will be more useful—Health, Safety, Conservation and Consumership.[14]

Health problem may be either of the individual or of the

community. The solution of the health problems depends upon science principles and hence science education.

Similarly proper science education can go a long way towards lowering the number of accidents, for many of the accidents have implications for the principles of science such as prevention of fires, safe driving, electric shock, etc.

Topics like the origin and structure of soils, erosion and its control, forests and floods, conservation of water power, irrigation, agencies of conservation, etc., come under conservation. Each of these has science-social significance.

Every individual is a potential consumer of goods, materials and services and therefore should have functional scientific knowledge to bring to bear on the problems which will confront him in this important area of living.

But whatever be the ways in which things are arranged, it is a matter of general agreement that knowledge imparted in science should be useful, interesting and graded to suit the age and intelligence of the child.

(2) *Science as a process.* Sir James Jeans once pointed out that "To many it is not knowledge but the quest for knowledge that gives the greater interest to thought—to travel hopefully is better than to arrive."[15] Science is also a way of thinking and aid for acquiring knowledge. "We have discovered that it is actually an aid in the search for knowledge to understand the nature of the knowledge we seek."[16] Merely by an acquisition of knowledge, one does not get the whole benefit that a science education can bring. It is to be learned and taught in a peculiar way. "If science is poorly taught and badly learnt, it is little more than burdening the mind with dead information and it could degenerate even into a new superstition."[17] In fact philosophers like the late Bertrand Russell have warned against science becoming a religion by itself. All these stress science as a process.

A deep study of the characteristic features of the Indian society, its norms, mores and institutions would reveal that, it is scientific thinking, outlook and attitude and not scientific information that it is lacking in. Even very famous scientists

strongly believe in and propagate superstitions. May be the impact of the highly religious environment in which they live, many of them have irrational belief in God, are strongly confessed of the supernatural powers of local *sanyasins*, priests, etc., and they generally submit themselves to astrology and other pseudo-sciences It was alleged in the Indian Parliament recently that when a sophisticated machine of a fertiliser factory went wrong, a priest was brought and *mantras* were chanted to set it right ! Again the first rocket from the Thumba station of Kerala was launched after making thorough studies about the 'Rahukala'. The sudden popularity certain 'incarnations of God' get in India is surprising. Even men of science are not free from this worship—not to speak of the common men. When scientists do this, it is not because of poor scientific knowledge but because of poor scientific outlook.

All these happen because science is neither taught nor learned in the way in which it ought have been. If we want to exploit the maximum from a course in science, it should be taught more as a process than as a product. Science as a process develops many qualities of heart. It disciplines the mind and sharpens intellect. It develops rationalistic thinking, maturity in outlook and broadness of heart, prevents rash conclusions and biased judgements, and above all a peculiar way of approaching and solving problems which is unique to science. The thinking process of a scientist is different from that of an ordinary man in that the former is well arranged and systematic. Referring to the scientfic method, Gordon Nunn writes, "Science without scientific method is not truly science, because it is in the very nature of science that it has been built up by following certain well-defined methods."[18] The scientist defines the problem, collects data from all sources, forms hypotheses and tests each of them and accepts the most befitting one after final verifications. He thinks inductively, deductively and analogically. All the previous hypotheses, whoever may be the intellectual giants who put them forward, if did not hold good before experimentation are rejected and new ones formed. Thus Aristotle, the father of science, is discarded for his unscientific nature. "Aristotle maintained that women have

fewer teeth than men, although he was twice married, it never occurred to him to verify this statement by examining his wives' mouths. He said that children will be healthier if conceived when the wind is in the north. One gathers that the two Mrs. Aristotles both had to run out and look at the weather cock every evening before going to bed."[10] Many hypotheses of scientists like Dalton and Newton are abandoned. Some aspects of Einstein's theory of relativity are being questioned by Dr. Sudarsan, an Indian scientist. Science is highly objective and it is not the person that matters, but the versatility of the hypotheses he puts forward.

Conclusion. The information that science provides and the qualities of mind and heart that it develops are indispensable for a successful living in the 20th century. Science being the only subject which is capable for all these, it is in the interests of the individual and society that it should form an inevitable part of the curriculum.

Summary

Science is both a product and a process. A study of it helps both the society and the individual. Science education is important for the society for developing scientific outlook among the members, for economic and agricultural progress, for modernisation and for inculcating certain qualities of mind and heart essential for democracy.

Science has informative and disciplinary value as far as the individual is concerned. It provides him with sufficient knowledge for a successful living, and also develops in him scientific outlook and attitude.

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CHAPTER II

INSTRUCTIONAL OBJECTIVES OF SCIENCE

The previous chapter establishes the importance of science as a curricular subject. It also hints that to get the maximum benefit from a course in science, it should be taught in a particular way. It is here that the science of education gets its importance. How should science be taught? What are the objectives to be realised by teaching science subjects?

What are objectives? By education, we try to bring about some desirable behavioural changes in the students. It is not a mere presentation of facts, but an attempt at developing new skills, new attitudes and new ways of thinking. "A science program must be judged by its effects on individual pupils, not by the number of text-book pages read or the percentage of a syllabus covered. Science can justify its place in the curriculum only when it produces important changes in young people—changes in their ways of thinking, in their habits of action and in the values they assign to what they have and what they do."[1] The various Education Commissions appointed by the Governments from time to time will decide what these objectives should be. In determining these, the commissions have to take many factors into consideration like the economic conditions, the needs of the community and individual, the stage of growth of the pupils, etc. These are major goals of education and has to be realised through a course of many years. These goals are very distant and practically will not be fully realised. It is the responsibility of educationists to formulate objectives for different stages and for different subjects. They are called stage-wise objectives and subject-wise objectives respectively. Each unit of the subject helps for certain behavioural changes to take place. Like that each lesson has also certain objectives. These are called unit-wise objectives and

lesson-wise objectives respectively. Whereas the stage-wise and subject-wise objectives are generally prescribed by specialists in the field, the unit-wise and lesson-wise objectives are to be formulated by teachers in the schools. The inter-relationship of different objectives can be represented as follows :

Broad-Educational objectives.

↓ ↑

Stage-wise objectives.

↓ ↑

Subject-wise objectives.

↓ ↑

Unit-wise objectives.

↓ ↑

Lesson-wise objectives.

Looking at this arrangement from the bottom, we find that the broad educational objectives have to be attained by realising the lesson-wise objectives.

Different objectives. The formulation of objectives should be in consonance with the general nature of science and its major goals. Science as a school subject being composed of both scientific knowledge and scientific mindedness, school programmes should be so developed as to acquire both these. Though objectives have been stated in different ways in different books and journals, on the ultimate analysis, they can be found to be built upon these two broad aspects of science—as a process and a product.

Criteria for the selection of objectives. Various criteria may be used for the selection of different objectives. The National Society for the Study of Education has put forward the following criteria :[2]

1. Should be practicable for the classroom teacher. It must be usable ; when properly used, it should lead logically from one step to the next, and if carefully followed, it should result in progress toward the objectives ultimately sought.

2. In the second place, the statement of objectives should be psychologically sound. It should be based on generally accepted principles of learning.

3. In the third place, the objectives should be possible of attainment under reasonably favourable circumstances and to a measurable degree.

4. In the fourth place, the selected objectives should be universal in a democratic society.

5. Finally, the statement of objectives and the explanatory context should indicate directly, or by clear implication the relationship of classroom activity to desired changes in human behaviour.

Thurber and Collette have also put forward five almost similar criteria.[3]

1. Usefulness. The desired learnings should have value in the lives of the pupils

2. Timeliness. Learning should be concerned with material familiar at the present time, not with obsolete devices and ideas.

3. Fitness. The learnings should fit into a sequence leading toward broad objectives.

4. Appropriateness. The learnings called for should be appropriate for the maturity and backgrounds of the pupils concerned.

5. Practicability. Experiences needed for the development of the learnings should be possible.

When objectives are formulated these criteria should be given due weightage.

Kinds of objectives. In 1947 the National Society for the Study of Education in America published the following objectives for science teaching :[4]

1. Functional information of facts.
2. Functional concepts.
3. Functional understanding of principles.
4. Instrumental skills.
5. Problem solving skills.
6. Attitudes.
7. Appreciations.
8. Interests.

David F. Miller and Glenn. W. Blaydes have proposed the following as the objectives of teaching biological sciences—the

acquisition of information, the development of Methods of thinking, the induction and application of principles and the formation of attitudes.[5]

John. S. Richardson[6] has suggested that the science teacher should teach in such ways that students will,

1. Develop the ability to think critically to use the methods of science effectively,

2. Acquire the principles, concepts, facts and appropriateness through which they can better understand and appreciate the nature of the earth, its inhabitants and the universe,

3. Use wisely and effectively the natural resources of our earth as well as the products of science and technology,

4. Understand the social functions of science and think and act in relation to the implications of science and technology for society,

5. Develop understandings that will contribute positively to their physical and mental health and their recreational interest, and

6. Acquire information, understandings and appreciations that will contribute to their educational and vocational guidance.

Mr. Narendra Vaidya[7] has listed the objectives in the following way and this seems to be highly acceptable in the Indian conditions.

1. Functional understandings :
   (*a*) Scientific vocabulary,
   (*b*) Scientific fact,
   (*c*) Scientific concept,
   (*d*) Application to new phenomena.
2. Scientific skills.
3. Scientific attitudes.
4. Scientific interests.
5. Scientific appreciations.

However a seminar of Training College Lecturers in Science subjects[8] of Kerala University held in 1967 has formulated objectives in detail and this has become popular all over South India. This is in line with the objectives proposed by the

NCERT and can be summed up as follows :

1. The pupil acquires knowledge of facts, terms, concepts, principles, etc., in the field of sciences.

2. The pupil develops understanding of facts, concepts, principles, processes, etc., in sciences.

3. The pupil applies scientific knowledge in a new or unfamiliar situation.

4. The pupil develops skill in drawing diagrams, manipulating apparatus, preserving specimens, improvisation, collection of information, scientific expression, observation, etc.

5. The pupil develops interest in the world of science.

6. The pupil develops scientific attitude, value and qualities and

7. The pupil develops a sense of application towards scientific phenomena.

The first three of these objectives belong to the cognitive domain, the fourth to the psychomotor domain and the rest to the affective domain. Though these objectives are classified for the sake of convenience, there cannot be any water-tight compartmentalisation in between them. On many occasions they may generally overlap. The objectives at the cognitive level are interdependent and form a hierarchy, knowledge being at the bottom and understanding and application making the superstructure.

A general discussion of these objectives will make them clearer.

1. *Knowledge.* It is the pre-requisite for all sorts of thinking in all subjects. It remains at the first level of learning and does not refer to a deep understanding at all. On the contrary it only denotes a parrot-like memorization of scientific vocabulary, facts and concepts. The knowledge can be considered to be realised if the pupils can recall or recognise things or read information from various forms of representation of data like maps, charts, diagrams, graphs, etc.

2. *Understanding.* In the hands of a self-thinking child, knowledge develops into understanding. In this stage, the content has become a digested piece of information with the child. The child can be said to have developed understanding

of the subject matter, if he can illustrate a phenomenon or principle, give experimental or theoretical proof, identify relationships, discriminate, compare and contrast, scrutinize statements, interpret, detect errors, express scientific ideas, judge the adequacy of given data, use appropriate units, assess the various sources of errors, see relationships, make simple calculations based on scientific relationships, cite examples, classify items and explain a happening or phenomenon.

3. *Application.* Science has acquired so much importance, because of its relevance to the environment and day to-day life of the child. A mere knowledge or understanding of science won't help the individual much, unless he is able to apply the knowledge in new situations. Therefore teaching should always be for developing the capacities of application. Capacity for application enables the child to formulate definitions, substantiate arguments, analyse a situation or problem, suggest hypothesis, give new illustrations of a principle, develop an experimental procedure to test or verify a given situation or hypothesis, modify or develop alternate experimenal procedure, select apparatus, procedure, etc., with a purpose, suggest a plan to improvise a scientific appliance, find reasons for a phenomenon, predict a happening, draw inference from relevant facts or data, find new uses for various appliances, locate a problem, establish relationship between cause and effect, describe apparatus set-up, experimental procedure, etc., express ideas cogently, coherently and precisely and also to arrive at generalisations.

4. *Skill.* There are three kinds of skills which can be developed as a result of the study of General Science, concrete skills like experimental skill, collecting skills, preservation skill, improvisation skill, etc., general skills like reading skill, writing skill, drawing skill, listening skill, computation skill and planning skill, etc., and also abstract skills like ability to recognise and classify things, ability to analyse simple problematic situations, ability to judge absurdities, irrelevancies and fallacies and the development of insight into the assumptions and nature of proof, etc. Skills involve physical and mental performances. There is more scope for the development of all these skills in biological sciences than in Physical Sciences.

5. *Scientific interest.* It is the task of science education to see that the children feel alive in the environment in which they live. The role of interest comes here. "The science teacher has many devices not present in other areas for creating and sustaining interest ; the natural desire of young people to experiment, the lure of science equipment such as microscopes and telescopes, the interest in taking things apart, the science club and others."[9] The long-term abiding interests in science may lead to vocational or avocational pursuits or in the development of life-long hobbies. Interests, however, should not be super-imposed. The child should develop activities according to his own inner appeal. Giving students ample chances for the following activities may develop scientific interest in them—visiting places of scientific interest, making collections of specimens, making improvised apparatus, making simple preparations, reading scientific journals, engagement in scientific hobbies and science club activities, observation of natural phenomena and also contribution to school science magazine.

6. *Scientific attitude.* Attitude is a condition of readiness for a certain type of activity. It is a mental-motor set of the individual which is characterised by predisposition towards objects, persons or events and a tendency to act. Attitudes vary with individuals and time. It may be simple or complex, stable or unstable, temporary or permanent and superficial or fundamental. Well planned teaching situations, direct meaningful and purposeful activities, adequate experimentation, verification, etc., build up right attitudes in children. India being a highly superstitious society, science teaching should always be planned to develop right attitudes. Some characteristics of this scientific temper are intellectual honesty, objectivity in drawing conclusions, adoption of scientific and systematic procedure, open-mindedness in receiving new ideas and facts, curiosity, readiness to reconsider one's own judgements, spirit of team work, self-help and self-reliance, intellectual satisfaction from scientific pursuits, economy in use of materials, honest recording and reporting of observation, faith in cause-effect relationship, pursuing activities with consistency, preparedness to face hardships and difficulties, a sense of dedication, faith in specia-

lists in their respective fields and at the same time a complete rejection of the principle of authority and also an eagerness to know and understand things.

7. *Scientific appreciation.* "Scientists of all races and of all lands have disclosed to all of us, the mysteries of nature. Our efforts should not therefore be confined to the teaching of understandings alone because the concomitant elements of admiration, emotion and intellectual pleasure cannot be altogether easily discarded."[10] As pointed out by Wheeler and Perkins,[11] "the intelligence which education calculated to develop will not grow when uprooted from the background of feeling from which it springs." Again "Adjustments to the situations encountered in modern living are not made on the basis of cold factual applications alone, but also with feeling and emotion. Each adjustment situation is a complex of feelings, attitudes and understandings. It would seem then that a background of appreciations which are peculiar to science should become one of the desired outcomes of instruction in this area."[12] The content in science if developed in an evolutionary manner would reveal the fascinating historical and biographical incidents, stories of scientific romance, privation and adventures, etc., which provide for emotional satisfactions and develop emotional depth. Appreciation cannot be taught as such. It develops from understandings and attitudes. History of science, biographies of scientists, impact of modern science etc. provide ample scope for appreciations. The capacity for appreciation enables the pupils to realise the significance of various discoveries and their impact on human life and society, to value the sacrifices and painstaking efforts made and hardships undergone by scientists in the course of their discoveries, to get excitement and thrill at every significant scientific achievements, to show eagerness to convey their joy and thrill to others, to show respect and admiration for great scientists and to realise the importance of science in human progress.

Conclusion. The above discussion brings out the objectives broadly classified. Science being an everchanging and evergrowing subject the objectives should also change and grow

correspondingly. The present tendency is to give more importance for affective domain of teaching science than to the cognitive domain. Unfortunately, the objectives of the affective domain are comparatively vague and it is difficult to measure and find out whether these objectives have been realised or not with the existing evaluation tools.

Summary

Objectives form the guide-posts for teachers in providing learning experiences. Different people have categorised the objectives in different ways. Usefulness, timeliness, fitness, appropriateness and practicability form the criteria for the selection of objectives. Objectives are from the cognitive, psychomotor and affective domains. Knowledge, understanding and application are of the cognitive level, skill at the psychomotor level and interest, attitude and appreciation at the affective level. Success of teaching depends upon the realisation of these objectives.

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SECTION II

WHAT SCIENCE ?

CHAPTER III

FACTORS WHICH INFLUENCE CURRICULUM CONSTRUCTION

What is curriculum? As per the traditional and narrow conception, curriculum meant only the formal academic lessons prescribed for study. But this conception has changed and now curriculum means the totality of experiences that the pupils receive in the school. Many activities once considered co-curricular and extra-curricular have become curricular now. Everything that the child experiences in the class, in the laboratory, work-shop, library, play grounds etc., is curricular. The social opportunities of the school form a very significant part of it. Even the interpersonal relationships of students and teachers can be included in the new concept of the curriculum.

Whatever may be the concept of the curriculum, it has a very important role to play in the educational process. When arranged in the order of importance, it occupies a place next to the teachers and the taught.[1] Since the outcomes of education largely depend on what is taught also, the construction of the curriculum should be done only very carefully. This is all the more true with regard to science teaching. Science is so wide and deep a subject, with a number of branches and sub-branches, requiring a lot of skill and intelligence to master it, that one cannot include the whole of scientific knowledge available in any course of study however long and ambitious it be. Only certain relevant aspects can be included. This relevance in its turn depends upon so many factors.

Factors which influence the selection of science material. There are so many factors which directly and indirectly influence the inclusion of content materials in the curriculum. In fact there cannot be any one criterion for the selection of the subject matter, nor can there be any strict principle controlling

this. There are only certain broad outlines which control from behind the framing of the curriculum. They are the following :

1. *The objectives and nature of the course.* It is for the realisation of certain objectives that any course is organised. The selected materials for the curriculum should enable the realisation of these goals. For examples, if the main goal of education is enabling the students to be fit citizens of a democratic social order, then lessons depicting the glories of monarchs, the values of implicit obedience, etc., should not find a place in the text books. Similarly if the objective is to turn out physicians, then a course in art, literature, etc., will be useless. Similarly for an engineer a study of biological sciences will not be of much use.

Therefore what we should include in our text books of the secondary schools will depend upon the objectives laid out by the various commission reports and by the state and central governments. Fortunately the Kothari Commission report has given prime importance for the study of science. The State Governments are now in the process of allotting more and more periods for the teaching of science. That means that more and more scientific knowledge can be imparted at the secondary school stage.

2. *The duration of the course.* The length of the course also determines the selection of the materials. No formal education can continue till the grave-yard. Since the time is limited, the knowledge that is to be imparted should also be limited. The Kothari Commission has recommended a course of ten years at the school level, both Primary and Secondary.[2] In addition to that two years' Higher Secondary education is also recommended. The working day within this short span is to be divided among the various subjects. This means that science as a school subject will get only limited time, which in turn is to be distributed among its various branches. Thus the time factor requires the inclusion of the 'must' alone in the science curriculum.

3. *Availability of resources.* Any programme chalked out must be practical. If there are strong barriers resisting its implementation, that programme won't serve any purpose.

Therefore when constructing a curriculum, one should see whether it is really implementable or not. Lack of well-trained teachers, laboratories, adequate text books and work books, standard tests, enriching materials in the mother-tongue, etc., are very strong barriers in the implementation of any science programme in India. There are teachers and teachers with many University Degrees, but they are generally ignorant of the modern trends. They are traditional type of teachers and the scientific mind is not developed in children. The condition of our school laboratories is most pitiable. There are many schools without laboratories and where there are laboratories, they are found lacking in suitable equipments and chemicals. The position of our extra-reading materials is pathetic. In many regional languages there are practically none at all. Even where they are available, they won't really serve the purpose.

4. *Interests of society.* More than a social service, education has now become a social investment. Society wants certain goals to be realised through education. That is why all socialistic governments have nationalised education. Society wants its cultural heritage to be assimilated, improved upon and transmitted to the next generation. Any course of study should help this purpose.

But this is only a major long-range goal. There are so many immediate objectives which are connected to this long-range goal. They influence the selection of the content material profoundly. They can be summed up as follows.

(*a*) *The vocational requirements of the society.* The society is a complicated institution with so many systems to maintain like the transport system, communication system, production system, food supply system etc. All these require specially skilled and trained personnel for their successful function. It is the responsibility of the educational system to supply them. Therefore if at one stage the society is in need of persons trained in a particular vocation, then the educational system will be naturally oriented towards that. This means the vocationalisation of education. There is a traditional aversion towards the vocationalisation of liberal education. This has been

condemned by A. N. Whitehead as follows : "The antithesis between a technical and a liberal education is fallacious. There can be no adequate technical education which is not liberal and no liberal education which is not technical : that is no education, which does not impart both technique and intellectual vision."[3] Science education is no exemption from this. The topics we select should directly or indirectly serve the vocational requirements of the society.

(*b*) *The progress of the society.* The society is relatively static when compared to the dynamic individual. There is always a strive for progress from the society's part. This can be achieved through the dynamic individuals and this in turn through education, especially science education. Though all science subjects make pupils progressive, the lessons selected should be presented so as to enable them to break their conservatism and bring about a thorough change in their attitude. There are instances of the feeling that an enemy country is more progressed, bringing tremendous changes in the curriculum For instance, many new science projects like the Physical Science Study Committee, Chemical Education Material Study, Biological Sciences Study Committee, etc., had their origin in America around 1957 becarse of the recognition of a lag behind Russia in certain scientific and technological fields.[4] Like that the entry of China in the Nuclear Club has put India under mounting pressure and the spur our education has nowadays is also because of the feeling of a lag behind China.

(*c*) *The integrity of the society.* A society is composed of individuals with common objectives. The growth of the society sometimes results in its disintegration. No society can tolerate this as its flourishing depends upon it's integrity. Education should develop in the individuals, a sense of belongingness and a feeling of attachment to the society. Inclusion of materials which reveal to the students, the contribution one's society has made to human progress, depicting the biographies of scientists of the native land, presenting science so as to develop good discipline, etc., will add to the integrity of the society.

(*d*) *International consciousness.* The ideal of internationa-

lism is not new to this century. But in this nuclear age, it has gained added significance Science is the most universal of all school subjects and therefore it can do much in this regard. Internationalism can be infused by including in the science syllabus, the life histories of scientists, their achievements and contributions, the interdependence of the world science, etc.

5. *Interests of the individual.* From the point of view of the child, education should be life itself in all its multitudinous manifestations. As a result of psychologising education and many research findings the child has gathered momentum and is now the most important factor in the educational process. The survival of any system of education will ultimately depend upon its pertinence to the life of the child. For him the following aspects are important.

(*a*) *Utility*. Only those pieces of scientific information which are useful to the child in his ordinary daily life need alone be imparted through education. For a modern living scientific knowledge is inevitable. But overfeeding is harmful and also there is no time for it. Only relevant knowledge which would ensure a happy living and which would enable him to adapt himself to his changing environment need be given. Even that is to be presented in such a way as to be of help to him in practical life situations. In this respect, the present science education is a failure. The student may be a master of the whole of electronics, but in the home when he is to operate a radio or to replace a fuse wire, he proves himself helpless. Topics in hygiene, communication system, plants and agriculture, etc, should be given more importance in the curriculum.

(*b*) *The vocational requirements of the child.* Education for the child is a preparation for life, if not life itself. He spends many years in the school and after that there is a legitimate claim for him for a job. If the whole years he has spent in the school did not give him any training at all for that, then it is a criminal negligence. A study of science if properly done gives ample scope for employment in the fields of medicine, transport, communication, agriculture, etc. Science education should be given a vocational bias and relevant knowledge for this should find a prominent place.

(*c*) *Development of innate powers.* In the olden days subjects were included in the curriculum, according to their power for disciplining the mind. But now it has been recognised that the subjects as such have no disciplining capacity at all, but it is the way of presentation which determines the whole thing. By a mere passive presentation, the intelligence cannot be sharpened. But the whole content material should be a challenge for the students, so many problems to be solved, so many projects and activities to be undertaken. In this regard science is the most fortunately placed subject. But all the areas of science cannot be presented as projects and problems. Therefore topics which are vulnerable for an exciting presentation must find preference in the science curriculum. 'Activity Curriculum' and 'Project Method' are favourite words now.

(*d*) *Needs and interests.* Two children are never alike. Their intelligence, achievements, ambitions, interests, etc., vary widely. Their intellectual, social and motor needs are different. A child-centred education cannot neglect these factors. The child is interested in communication, enquiry, construction and artistic creation. If learning experiences and activities are based on such interests and needs, knowledge will be acquired and skills will be developed, not as ends but as tools in the satisfaction of felt needs. Learning becomes a pleasant job. But we cannot follow this as a strict principle since in that case, a separate curriculum has to be framed for each child. This, obviously, is an impossibility. What is all possible is making the curriculum as flexible as possible giving the pupil maximum liberty. This in a general way may touch the interests of different children.

(*e*) *Variety and flexibility.* No curriculum should be narrow and rigid. This creates boredom and narrowness of interests. The harmonious developments of persons being the aim, it should touch all aspects of the human personality and of life in a balanced way. Therefore the topics selected for the curriculum should have introductory, practical, preparatory, socialising, instrumental and cultural values. They should be adaptable to individual needs, interests and abilities and to local

conditions. There should be a happy balance between subject learning, experience and activity. It should not restrict the intelligent child, nor should it neglect the dull. It should be vulnerable to modern methods of teaching. The teachers and students should get maximum liberty to deviate from it whenever necessary.

(*f*) *Leisure time pursuits.* An educated man is defined as a person who knows to use his leisure time properly. 'An idle mind is the devil's workshop'. An unoccupied person thinks along anti-social directions. Therefore it is the interest of the society also to train the individual for the judicious use of his leisure time. The science subjects can train the individual in a variety of hobbies like photography, nature study, etc. Therefore in selecting topics for the science course, topics concerned with hobbies must also find their place.

(*g*) *Socialising the individual.* Any education should develop in the individual, knowledge, habits, skills, interests and sentiments that make him fit to live and fit to live with. Man is born into this world with many animal instincts and brutal passions. There are so many angularities around his personality. It is the responsibility of education to gradually rub off these angularities and make him a polished and refined individual.

That science is quite inhuman in its nature is a usual charge levelled against it. It is mainly so because of the many harmful weapons developed by science. Many conveniently forget the comforts science has brought to them. Science is the sum total of the achievements of many personalities who have dedicated themselves for the cause of the society. It is the real romance of science. The life histories of scientists, the hardships they have undergone, the social impacts of their contribution, etc , have high socialising value.

But it is in another way that a study of science helps the rubbing of the angularities. The science curriculum offers so many projects which can be undertaken on a group basis. When the children mix and mingle in the project, they gradually smoothen their personality also.

(*h*) *Correlation.* Though there are different subjects taught, it is the same child who learns. Learning to be meaningful for him, should be properly correlated. Subjects are the result of the artificial classification of knowledge, of course, for the sake of convenience. But if they are presented in watertight compartments, it would look artificial for the child too. Therefore materials of different areas must have as much correlation as possible. In general the whole process of education should be correlated to life also.

Special factors to be considered in the high school curriculum

Discussed above are some salient factors of curriculum construction. They hold good not only at the secondary level, but on all the other stages of science education too. But there are some special factors that should be considered in establishing frames of reference for the teaching of science in secondary schools. Lacey puts forward the following list of factors in this regard.[5]

1. Science teachers are responsible for the major science learning of all pupils in the schools.

2. Only very small percentage of the pupils will ever pursue science in any formal way after their general education is completed.

3. All normal pupils should be considered capable of learning the basic principles and concepts of science.

4. The process of science – methods, techniques, strategies and tactics—are far more important in teachnig science than are merely its products.

5 All science fields are inextricably related by certain fundamental principles and concepts, the divisions between the sciences are artificial and barriers to the integration of sciences are reflections of man's inadequacies.

6. Many scientific concepts and experiences previously reserved for late high school or college presentation can be learned successfully by pupils at much earlier periods than has been assumed.

7. Science teaching approaches the level of a profession only as individual science teachers professionalise themselves and their work.

8. Science teaching while primarily a part of the general educational enterprise is inextricably tied to the scientific enterprise.

9. The effective science teacher must be reasonably proficient as a scientist as well as a teacher of young people.

10. Teaching science to Kindergarten children or junior high school pupils is just as important as teaching high school seniors and can be just as rewarding.

11. Except in very specific circumstances, all pre-collegiate science teaching should aim primarily at increasing scientific literacy for effective living.

Conclusion. The criteria mentioned previously form only very broad principles for the selection of content materials. Many of them hold good for all the subjects. Whatever may be the matter selected, it should ultimately equip the individual for the battle of life, and make him an intelligent citizen, knowing the past, interested in the present and hopeful of the future of the community and the race.

Summary

There are many factors which decide, the selection of the science material for the school. The objectives and nature of the course, the duration of the course, the availability of resources, the interests of society and individual are some of them. There are many other factors which have special significance for the high school curriculum. All these are only very broad principles.

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CHAPTER IV

ORGANISATION AND PRESENTATION OF CURRICULUM

Merely by laying the objectives and selecting the content materials as per the specified principles, the realisation of the goals won't spontaneously take place. It depends largely on how the content materials are organised and presented in the curriculum and how skilfully the teacher develops them. Though according to the present set-up in India, the teacher has no place in the selection of the content material, he can take some liberty in its arrangement and presentation. Even this has been considerably mitigated by the insistence on text books and such other prescribed tools and also by many of the rules and regulations set up by the unintelligent and unresourceful administration. Yet for a science teacher much can be done even in this muddled set-up.

Organisation of content material. "When the principles of science that will form the basis for learning experiences in the course have been selected, it becomes necessary to so order these, that learning may be both efficient and effective. Upon the plan for organising materials may depend, in part, the extent to which certain desired outcomes are achieved. This is especially true of those outcomes that are somewhat less tangible such as attitudes, interests and skills of problem solving. These depend in a very real way upon the manner in which the selected content is ordered for learning."[1]

There are many ways in which the materials selected for the curriculum can be arranged and organised. According to H.N. Saunders,[2] the material can be arranged in any one of the following patterns :

(*a*) In the order of its discovery.

(*b*) According to some logical order ex :—that of each

separate specialised branch of science.

(*c*) By grouping around some central theme such as,

1. A main principle of science.

2. Phenomena which are of immediate and local interest to the pupil.

(*d*) According to the mental and emotional age of the pupil.

In addition to these possibilities and frequently forgotten in academic discussions on the subject are arrangements,

(*e*) To suit the teaching accommodation provided by the school.

(*f*) According to the capacities and preference of the available school staff.

These methods of organisation are not mutually exclusive. In a particular syllabus, their influence may vary—that is all.

(*a*) *Historical order.* In this way of organisation the subjects are arranged in the same sequence of their historical development. It is generally integrated with the logical way of organisation In the historical order, there are two possibilities of presentation, one centering around the subject and the other around the life histories of scientists. In the latter case it becomes highly vulnerable to the biographical method of teaching science. The historical organisation if properly treated, will enable the teacher to bring the whole romance and human element of science in the classroom. Unfortunately this is the least psychological of all ways of organisation.

(*b*) *The logical order.* Science is accumulated and systematised knowledge. Really it is this classification and codifying of knowledge which makes any branch of knowledge a science. The knowledge is logically arranged in science. But there are many possible arrangements—all equally logical. A logical course in chemistry may proceed from elements, compounds and mixtures or from known elements to binary compound and then to more complex compounds or may proceed in the order of the increasing atomic weight of elements, etc. In the biological sciences the structural pattern, the functional pattern, etc., may be followed.

This way of arrangement is quite in consensus with adult thinking and is quite good at the higher stages of education. But

if this is strictly followed at the lower stages it makes education harsh and austere. It is the child who learns and therefore his psychology must also play a vital role in arrangement. For him water is simpler than and must precede oxygen and hydrogen.

But if topics are logically arranged and psychologically presented it may bring good results.

(*c*) *Grouping of materials around a central theme.* This method is generally followed in advanced countries for both the presentation and the arrangement of the material. This is highly psychological and is most suitable for the modern methods of teaching science like the Unit, Project and Problem methods.

It is only the psychology of the mind to put all the correlated pieces of information together. When such connected facts are grouped around a central theme, a unit or project is formed. This grouping can be done in different ways.

1. *Grouping round a scientific principle.* This is the arrangement of an integrated curriculum, where the whole matter is developed around some matter of scientific interest, a scientific principle, a scientific theory or the measurement of a physical quantity. There are no subject barriers at all on many occasions. The following are some examples of this way of organisation. Centering around 'work', the whole idea of mechanics can be developed. Around 'energy' can be developed everything about animal and vegetable metabolism. Taking 'wave motion' as the core, the study of sound, measurement of frequency, the speed of light, electromagnetic spectrum, etc., can be arranged.

Many factors are to be considered to get the maximum effect from this arrangement. The topics selected should have real and practical educational value. The building of the subject around the central theme, should not look artificial. The pursuit of the topics should develop desirable skills and attitudes in pupils.

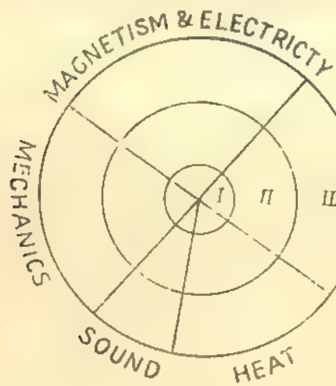
2. *Grouping around subjects of immediate interest to pupils.* This way of arrangement again is to make teaching-learning process more interesting and psychological. Children are

interested in their immediate environment very much. Any way of organisation which does not take this fact into consideration won't sustain the interest of the pupils. In this method which is highly inductive, examples are drawn from various branches of science so as to enable wide generalisations. Again the topics are presented in the form of questions or problems just to be a matter of challenge and excitation for the pupils. Gans, Almy and Burns[3] refer to this nature of the child as follows : "The young child is seldom concerned with the abstract. His interests lie rather in the specific and concrete. He does learn to generalise, but only through the gradual putting together of his experiences. He has however an inquiring turn of mind and like the true scientist is keenly interested as in "what would happen if ?" He builds a block structure so high it collapses, brings a pan of snow to the oven to test its baking qualities, takes apart the wind up toy some one has given him, pours all the paints at the easel together. To meet these interests, he needs an environment which is rich in materials for experimentation, and the guidance of one who is willing for him to carry on such problem solving activity." Saunders gives a concrete example as to how this enquiring nature of the child has to be utilised in education. 'What happens when things burn ?' may be a problem of immediate interest to the students around which may be collected the chemistry of oxidation, the physics of heat and its transference, the botany of plant respiration, the zoology of animals including human respiration, etc. The topic may lead to a further collection of associated material : to food and diet, to vitamins and catalysts, to various important catalytic processes such as the manufacture of margarine and artificial fertilisers. Oxidation and respiration may be connected with functions of the blood, the heart and thus with valves, pumps and so on."[4]

Like this around topics of immediate interests to the pupils, lessons can be developed in an interesting way. But there are many practical difficulties faced. As a piece of information is related to many sources, where to include it to get the maximum benefit, is a common problem. Again this way of arrangement like many other modern trends poses a

serious problem to the teachers. They have to be all knowing and versatile. Sometimes the developments of the topics become artificial and hence uninteresting.

(*d*) *Grouping around the child's stages of development.* It is the psychology of young children that they cannot sustain their attention in one type of activity for a long time. They want variety. Therefore various topics are to be introduced and should be developed gradually. The general science syllabus gives scope for this way of approach. The concentric system of drawing up syllabus is in tune with this approach. Here all topics are taught in all classes, the difference being only in the depth of the content matter. As the child grows, the subject also grows in ever widening concentric circles. In all the other systems, a topic is taken and is dealt with in detail at a stretch. Here the child may not be able to understand the advanced principles and concepts of a topic at lower stages. But in the concentric system complicated content areas are presented only when the child is mature enough for that, simpler facts being dealt with in the lower grades.



In the diagram is an example of concentric syllabus in physics in three different but continuous standards. Here we find that all subject areas are covered at all stages. A child discontinuing at any level will have some basic ideas about everything.

The system will be highly successful if one teacher handles the subject continuously in different years. When different teachers handle, there will be too much of repetition and the subject loses its freshness and power of appeal. The teacher should be very careful to see that the charm of the subject is not exhausted in the first year itself "There should be always new problems to be solved, new difficulties to be overcome, new mysteries and wonders to be seen."[5]

Presentation of the content material. Equally important as the organisation of the content material is its presentation. Materials should be presented in such a way so as to sustain the interest of the students. The technique of the presentation partially helps the realisation of many objectives of science teaching.

As the presentation of the content material is a very important thing in curriculum construction, it should be very carefully done. It should provide for the effective learning of scientific facts, concepts and principles. Learning through the natural psychological process should be adhered to. It should enable for the development of skills in problem solving and also develop qualities of scientific attitude and appreciations in the individual.

The various trends in the presentation of curriculum materials take into account the above directives. There is indeed no one best method of presentation as the suitability of one will depend upon the objectives to be realised ultimately.

1. *Presentation according to the logic of science.* If science as a product is more important than as a process, then this method of presentation has some value. Indeed this is the most traditional of all methods. It does not take into consideration the psychological principles that govern the child, but solely concentrate upon the logic of the subject. Though many advanced countries have discarded this way of presentation and arrangement from the secondary school syllabus, we are even now following it. Here it continues both as the method of presentation and organisation

In logical way of presentation subjects are organised under different heads. For example, in physics topics will have head-

ings like mechanics, statics, electricity, sound, etc. In chemistry it adopts the traditional system, occurrence, preparation, properties and uses. In biology there will be different sections like, Botany, Zoology, Physiology, etc.

Obviously this way of presentation will suit better only the higher grades. For children of the lower levels, this is unpsychological. The subject gets totally isolated from the life situations. It sometimes fails to bring about the romance of science in the classrooms. The presentation is inflexible and gives practically no scope for the teacher to exercise his liberty.

2. *Concept-centred presentation.* By concept will be meant a generalised notion, thought or idea made up of partial meanings. Many words that we regularly use in science are conceptual words (Ex. force, work, seed, fruit, etc.). One's concept of something is what he knows or feels about a thing. A scheme of presentation about the major concepts of science "may provide an integrated pattern of organisation reducing the number of topics and providing for the enlargement of concepts from level to level in the school programme."[6]

3. *Environment-centred presentation.* This is a psychological way of presenting things. In many foreign countries this has become the accepted technique of presentation both for Elementary Science courses and General Science courses and to some extent for special studies too. Here topics are presented relating them to the environment. This excites the interest of the child and helps his easy adaptation to the environment. "Children are so inquisitive about themselves and their environment, that it is a folly not to take advantage of the opportunity which they themselves offer us to teach them the things they are eager to know."[7] Natural resources in the immediate environment can be used for teaching. It provides for individual differences and allows a complete mastery of the content materials.

The general titles of the topic will be like, the air we breathe, the water we use, light in the home, living things, the control of disease, how do things keep alive ?, chemistry of the individual, learning to use machines, how does man adjust to air, etc. Sometimes, especially at the lower level, these chapters are

presented in the form of stories or dialogues which will make the whole thing more interesting for the child.

4. *Presentation centering around the maturing interest of the pupils.* This way of presentation has been based on a number of interest studies on school pupils of America. As the children grow, their interests also widen and vary. The presentation of the curriculum material should be based upon this fact.

As the interests of the child grow, curriculum should also grow in a spiral way. For example, the science course starts with science experiences having to do with the immediately personal problems of the learner and with simple understandings, proceeds with experiences dealing with the physical and community environment and ends by providing experience dealing with wider social significance of science and the use of science for the control of environment.

This program is highly psychological.

5. *Presentation in terms of types of adjustment.* Throughout our life we are engaged in the process of adjustment. According to Samual Butler, the very life process is "Nothing else than this process of accommodation, when we fail in it a little, we are stupid, when we fail flagrantly we are mad, when we suspend it temporarily we sleep, when we give up the attempt altogether we die."[8] The individual is in need of adjustment to many sources like self-personal adjustment, adjustments to the immediate social group, to the community, to the economic relationships, etc. If curriculum materials are presented taking these factors also into notice, then it will be of more use to the students.

6. *Presentation in accordance with human experience.* The process of education should be in consonance with human experience. In fact education should be human experience itself. Health, safety, conservation, recreation, etc., are broad areas of human experience. Therefore curriculum materials should also be presented under such titles. This new tendency is attracting the attention of educationists abroad.

7. *The unit-problem way of presentation.* This is a way of presentation suitable both to the environmental method and problem-solving method. In the environmental unit plan, the

mastery of the subject matter is a major objective, whereas in this method it is given only subsidiary importance, predominance being given for the development of problem solving skill, scientific outlook and attitudes. Here the unit is organised around a major problem, the child usually confronts in his life. For example, 'What happens to the water used by plants ?', 'Why does iron sheets rust ?', 'How are dissolved impurities removed from water ?', etc., may be common environmental unit problems. This method is highly flexible and because it is correlated with scientific method, develops in the child many qualities of scientists.

Some guiding principles in presentation. Regardless of the way of presenting materials, there are certain guiding principles which may be used as criteria in presentation.[9]

1. The content should be organised into large areas of units each of which represents some major problem of living, area of human experience or aspects of environment.
2. The content of any single area or unit should be broken down into smaller learning problems, which have interest, significance and usefulness to the learner.
3. The learning experience in any single problem should be organised to promote functional understandings, growth in instrumental skills, growth in the process of problem solving and in the development of attitudes, appreciations and interests.
4. Abundant opportunities should be provided both for building and applying concepts and principles.
5. Provision should be made for effective evaluation including self-evaluation.
6. The sequence of units should be planned to give recurrent contact with facts, concepts and principles of science and to provide a spiralling and enlarging pattern of growth in concepts and principles.
7. Problem situations should provide definite training in one or more of the elements of scientific method.
8. The course in science should be organised to provide frequent opportunity for pupils to participate in planning and to engage in individual and group projects.

Conclusion. Discussed above the certain traditional and modern trends in the presentation and arrangement of the curriculum. There is no one ideal way of presentation or organisation. The best thing is a combination of conflicting desirables. Many of the modern trends are only of theoretical importance to the science teachers in India and many other countries of the east, for here only the traditional types alone are followed without any inclination for adopting new techniques. Obviously this has brought its own defect and the poor standards in education are the result of this negligence also.

Summary

As important as the selection of the curricular materials is its organisation and presentation. The recent tendency is to present it in a way as to be impressive, interesting, appealing and psychological to the child. In the organisation also the same principles in different forms are followed.

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CHAPTER V

THE GENERAL DEFECTS OF OUR SCIENCE CURRICULUM

Education in India is described as a cruel play with the child. It is a vicious circle. There are occasional cries for its reorientation, but no one knows where to start with. Education being a highly integrated process, a change in any one field would necessitate corresponding changes in all the other areas. This would mean a lot of investment. The financially poor nations cannot afford to it.

Any change in the educational reconstruction in India should start with curriculum. The curriculum at all stages here is centuries old in all subjects, especially so in science. Even the comparatively modern science curriculum in America has been condemned by educationists there as backward by about 50 years. Science is so dynamic and progressive a subject that only a highly elastic and ever changing curriculum can be really a living one. The author is reminded of a statement by a remarkable personality. "The world is moving at such a rapid speed that we have to keep on running just to stay where we are". This remark holds good in all its dimensions to curricular reconstruction also.

The science curriculum of the Indian schools is so outdated that there cannot be a single favourable point to support and substantiate its continued existence. The only surprise is how it continues to exist and there cannot be a definite single answer for that. Listed below are the general drawbacks of our syllabus.

1. *The science curriculum is narrowly conceived.* The curriculum is only a means for the realisation of certain goals and not end by itself. Unfortunately our science curriculum is not framed in consonance with the major objectives to be realised

by a teaching of science. It has just prescribed certain topics and arranged them in some form of logical order. How the study of these subjects helps the students on their life situations is not considered at all. The main objective is preparing students for university courses. No wonder that the certificate given at the end of the successful completion of the Secondary Course is "Eligible for admission to a course in the University" or something of that sort. The curriculum is independent of and ignorant about the major objectives of science teaching in India.

2. *It is highly theoretical.* Science is taught in our schools merely and solely for imparting scientific information. But scientific knowledge is only one side of science. Equally important is the development of the scientific mind--scientific attitude, outlook, etc., and skills in problem solving and manipulation. At the secondary school level in India and in many countries of Asia, science is taught only as theory with no provision for laboratory experiences. Not only that, scientific information is imparted so directly that it becomes highly bookish and liberal, no chances being given for training in scientific method or for developing problem solving skill. Thus science is considered as a product alone, whereas, it as a process, which is more important, is neglected.

3. *Overcrowding of materials.* In our ambition to make the syllabus as up-to-date as possible, we are adding all possible information every year thus enlarging the syllabus. But unfortunately, this overcrowding does not bring the desired effects. It taxes the child very much and he has to memorize just as a parrot many things quite useless to him in his daily life. Even at the low grades atomic fusion and fission are taught. What is the result of all these ? The frustrated child develops an aversion and disgust for the subject altogether. Strange enough, though there is overcrowding, it is lacking in many pieces of useful and essential information.

4. *There is no provision for the development of scientific attitudes and skills.* One of the major objectives of teaching and learning science is to develop a scientific mentality. For

this science is to be taught more as a process than as a product. The development of this outlook is a natural but complicated process--so many problems are to be solved, so many experiences to be undergone, and so many projects to be undertaken. Our present-day syllabus because of its rigidity and inflexibility won't permit neither the teacher nor the pupils to deviate from it even slightly. This means that the student gets only scientific knowledge and all the other personality traits to be developed is left uncared and undone. Scientific skills are neglected. The student gets no experience in the laboratory. Even where experiences can be provided without the laboratory, many other factors intervene, disallowing the students, to enjoy the privilege of getting them.

5. *The syllabus is not in tune with the varying needs and interests of the students.* The children are not miniature adults. They have a different psychology of their own. The logical and topical arrangements of the subject matter in the curriculum won't excite them at all. They want something to act, something to do, something to live. All their senses should be fed as a result of the educational process. In fact the whole scientific knowledge is knowledge acquired through the senses. As Mr. E.P. Hubble has remarked, "Equipped with his five senses, man explores the universe around him and calls the adventure science."[1]

In this regard the present syllabus is unsuitable to the students in two ways. The general treatment of the syllabus is quite uninteresting to the student. Apart from this, it will not cater for individual differences in needs and interests. Children vary widely and different children are interested in different things. Their needs also are varying. Boys may be in need of a course around agriculture and industries, whereas girls may get benefit from a course oriented towards Home Science. The psychology of the child during the various stages of his development is not considered in the organisation of the syllabus. Again it is a uniform syllabus for both the dull and the bright alike. Individual talents are not considered at all.

6. *It is rigid and uniform* Children are interested in getting first-hand experiences from their immediate environment. The

environmental differences are not given any weightage at all in the present curriculum. The curriculum has no bearing upon the immediate environment of the pupils and *vice-versa.* Even when attempts are made to bring about a correlation between the environment and the curriculum the variation in the environment in different parts of the country is not looked into. A curriculum totally isolated from the environment of the pupils becomes meaningless and lifeless for them. Now the rural schools and urban schools are to follow the same scheme : no difference at all in the curriculum of the schools of both the sea-shores and the mountain side.

7. *The domination of the examination.* The examinations have become necessary evils. On all areas of our education it has now got its ugly influence. Unfortunately it is only for grading and not for evaluating and remedial teaching that examinations are conducted here. As the tyranny of the examination continues, teachers resort to 'coaching' rather than educating. Many of the activities that are possible both in the curricular and co-curricular fields of science are made 'impossibles' by the domination of the examinations. It seems, sometimes, that it is for the examination, that contents are selected and organised. All the activities in the school are controlled by the examinations and the actual spirit of education has said farewell to our educational institutions.

8. *There is no vocational bias for the science programmes.* This cannot be said to be a defect, but taking into consideration our economic set-up, this looks so. Many areas of science are susceptible to a vocational treatment. But the science curriculum, as we follow now, gives no such treatment at all. Again science can give training for so many leisure time pursuits—this also is neglected by the curriculum-makers.

9. *The syllabus does not bring to light the life and spirit of science.* Referring to the functions of learning science in the secondary modern schools Mr. Gorden Nunn says, "The first function is the inculcation of the spirit of science. This in my opinion is the most important function."[2] A mention of science at present first commits to memory its destructive potentialities than the service it is rendering to humanity. This is

so because of wrong methods of teaching and insufficient curricular development. The science teacher should enable the students to think critically and to arrive at their own conclusions in the matter. "The critical mind will recognise that if man's intelligence is able to develop such inventions as explosives—which are demonstrably neither good nor bad in themselves—it must also become able to progressively stamp out their destructive and to increase their positive applications. The teachers' task is to help develop such critical minds. He should recognise that the humblest of inventions are also equipotentially good or evil according to man's purpose. Ships, shoes and sealing wax no less than dynamite can be used in the process of destruction."[3]

Science has brought more good than harm to the world. It is a subject dedicated to the service of humanity and it has a romance in so doing. A careful study of the history of science and life histories of scientists would reveal these facts. Unfortunately our syllabus does not permit such a biographical approach. The life of science is taken away from the topics and knowledge is presented as pieces of uninspiring, dead information. Generally our students are not interested in a course of science as it is quite dragging for them. The pursuit of science for its own purpose has become a rare phenomenon among our student folk

The life of science is also lost from the schools for our heritage in science is not properly revealed to our students. The students have become absolutely ignorant of our contribution in the fields of Mathematics, Astronomy, Alchemy, Medicine, etc.

10. *The science curriculum does not prepare the child for life.* Education should be preparation for life through life. As we are living in a scientific, technocratic society, a knowledge of science has become inevitable to enable any individual to adjust himself to his environment. The point is how far our science curriculum enables for this adjustment. It is admitted that it does to some extent, but far far below the expectations. It is all because of its highly theoretical nature.

Conclusion. Thus an analysis of our science curriculum would unveil, the most pitiable position in which we are placed.

Other countries around us have gone much ahead in this matter and yet are unsatisfied and conducting further experiments in this field. It is a ray of hope that the National Council for Educational Research and Training and also the various State Institutes of Education are thinking along lines of curricular reconstruction.

Summary

Our science curriculum has many defects. It is narrowly conceived, highly theoretical, overcrowded, rigid and uniform and examination dominated. There is no provision for the development of scientific mindedness and no vocational bias is given in treatment. It is not in tune with the needs and interests of the students and does not bring to light the life and spirit of science. Above all it fails to prepare the child for life.

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CHAPTER VI

MODERN TRENDS IN CURRICULUM DEVELOPMENTS ABROAD.[1]

There cannot be a perfect curriculum in any subject at any time. At the most we can near perfection—that is all. In America and such other progressive countries they have a dynamic curriculum. Yet there is a strong sway of dissatisfaction which results in further experimentation with curricular materials. Thus in all subjects new trends can be observed in curriculum construction. They generally evolve centering around universities and other study groups.

In Mathematics there are many experimental approaches going on. The School Mathematics Study Group, Greater Cleveland Mathematics Programme, The Madison Project of the Syracuse University and Webster College, University of Illinois Committee on School Mathematics, University of Illinois Arithemetic Project, University of Maryland Mathematics Project etc. are of great interest. Among them the School Mathematics Study Group (SMSG) has become very popular recently. The Computer-based Mathematics Instruction Programme is also worth mentioning. It is sponsored by Mr. Patrick Suppes of Stanford University.

In the field of social sciences, The Social Studies Program in Research, Social Studies Curriculum Program, Greater Cleveland Social Science Program, High School Ceography Project, Anthropology Curriculum Study Project, The Developmental Economic Education Programme, Elkhart Experiment in Economic Education, Sociological Resources for Secondary Schools etc. are important.

In the field of Material Sciences also, there are many projects going on. A serious rethinking about the reformation of the American Science curriculum started in 1950's. There

are many factors which influenced this rethinking. Lacey has listed them as follows :—[2]

1. The accelerated accumulation of scientific knowledge and the increased importance of the scientific enterprise.

2. The impact of the atomic (nuclear) age.

3. Technological advances and their effects on society (automation and cybernetics).

4. The recognition of a lag behind Russia in certain scientific and technological fields.

5. The advent of the space age when the first man made satellites were successfully orbited (1957).

6. The many criticisms directed at schools, teachers and school administrators

7. The phenomenal growth of the secondary school population and the expanded functions of the high school.

8. The increased availability of technological devices for improving instruction.

9. Increased accumulation of reliable information about human learning.

10. The growing realisation by non-scientists (both educators and laymen) of the real nature of science and scientific knowledge.

11. The increased involvement of the Federal Government and Private enterprise, both in working and administrative staffs and in providing huge sums of money for improving education.

12. The increased participation in curriculum development by scientists and scholars from all fields.

These new programmes try to present science more as a process trying to train the students in the techniques and methods of science. "The basic purpose of those involved in curriculum improvement has been to see that science instruction presents recent developments in science and a reinterpretation of knowledge which has been established earlier. Curriculum experts believe that science courses should be developed which provide students with experiences that show how facts are obtained and new techniques are developed. These experts also believe that science programmes developed in this manner

can produce a more scientifically literate citizen who is better able to cope with the problems of every day living".[3]

Many of these programmes centred around colleges and universities and got financial help from National Science Foundation and other sources. Though in the area of different sciences, they had a common pattern Lacey arranges them as follows :[4].

1. Obtaining financial aid from the National Science Foundation and other sources.
2. Enlisting the aid of College and University specialists in designing and writing new curricular materials.
3. Enlisting the aid of high school science teachers in all aspects of the studies.
4. Conducting Summer writing conferences to which the participating University and high school personnel were invited to help, develop and refine curricular materials.
5. Furnishing trial curricular materials to schools that wished to use them.
6. Sponsoring Summer Institutes in which secondary school teachers could be trained to use the new materials effectively.
7. Evaluating the effectiveness of new materials in the schools that tried them.
8. Developing supplementary materials, such as simplified apparatus, films, laboratory guides, models and teacher's guides, in addition to writing text books for most of the disciplines involved.

The Biological Sciences Curriculum Study, Chemical Bond Approach Project, Chemical Education Material Study, Physical Science Study Committee, Science Curriculum Improvement Study, Elementary Science Study, Science a Process Approach etc. are the most important among these projects.

The Biological Sciences Curriculum Study (BSCS)

The objective of this programme is to improve biological education at all levels, elementary, collegiate, professional and graduate. The BSCS first turned its attention to the secondary school, which it considers the pivotal level in American education.

The BSCS has three sets of parallel materials, a Green, Yellow and Blue version—each differing in approach. A fourth version for the lower ability students is also published recently. The study was organised in 1959 by the Education Committee of the American Institute of Biological Sciences under the guidance of Mr. Bentley Glass and Arnold Grobman. It is supported by Rockfeller, Asia and National Science Foundations. The committee was of opinion that biology taught in schools in 1960 was from twenty to hundred years behind the available knowledge in science. To meet the demands of a modern curriculum in biology, some sensitive topics such as evolution and human reproduction etc. are to be included. Biology must be presented as a changing science, abandoning cut-and-dried laboratory experiments and allowing the students to get involved in discovery.

Nine unifying themes run through the three versions of BSCS biology. While there is a difference in approach and emphasis, each version represents a one-year general biology course. The Green version emphasises the biological community, beginning with the complexity and diversity of life and coming to cellular structure relatively late in the course. The Blue version stresses physiological and biochemical evolutionary process with emphasis on the contributions that molecular biology has made to the general understanding of the universe. The Yellow version emphasizes cellular biology. The materials for the lower ability students treat the same themes, but presentation, is at a slower pace and greater variety of teaching techniques is suggested. A second level course is designed to follow the regular BSCS course.

The BSCS approach stresses investigation. The universal rather than applied aspects of biology are given prominence. The laboratory is used for explanatory and investigative experiments. The whole programme is different from the traditional courses in that they place greater emphasis on molecular and cellular biology on the community and world biome and on the study of populations.

Chemical Bond Approach Project (CBA)

The objectives of the Chemical Bond Approach are[5]

(1) To design an updated introductory course in chemistry that demonstrates to students, early in their exposure, the inherent fascination of chemistry as a discipline ;

(2) To prepare a new text book and laboratory materials to achieve these objectives ; and

(3) To help high school chemistry teachers update and strengthen their backgrounds in chemistry.

"The Chemical Bond Approach is an attempt to develop an introductory chemistry course which presents modern chemistry to beginning students. The presentation is intended to give students a preliminary understanding of what chemistry is about rather than simply an encyclopedic collection of chemical reactions and laboratory techniques or a mere overview of diverse conclusions held by chemists today. Such a course must be an organised one in which the pattern reflects the structure of the discipline itself. Since conceptual schemes play a major role in the organisation of chemistry to-day, the organisation of the course in chemistry is best based on conceptual schemes".[6] Thus the course is centred around chemical bonds, the ties between atoms as the making and breaking of these ties between atoms is chemistry. The logical implications of experimental facts is presented to the students. The project emphasises laboratory work which is designed to develop in the students the ability to identify a problem, to design an experiment that will shed light on this problem, to carry out the technical operations of the experiment and to arrive at a conclusion based on analysis of his own data. Assistance is gradually withdrawn until the student finally performs all the steps independently, employing techniques he has learned from exploration of earlier problems. The class and laboratory programmes run parallel and re-inforce each other.

Instructional and evaluation materials suitable to the project are also published. This scheme has support from the National Science Foundation but has not yet been integrated into the pre-service education of teachers as a common acceptance given

to it would necessitate a restructuring of all fields of higher education.

Chemical Education Material Study (CHEM Study)

The Project took its form during the years 1960-64. The course was such an attractive one, that during 1965-66 about 350,000 students in the United States were using CHEM study materials. Arther Campbell was the director of the project. The main objectives of the course are[7]

(1) To diminish the separation between scientists and teachers in the understanding of science ;

(2) To stimulate and prepare those high school students who plan to continue the study of chemistry in College in preparation for a professional career ;

(3) To further in those students who do not continue after high school an understanding of the importance of science in human activities ;

(4) To encourage teachers to undertake further study of chemistry in courses that are geared to keep pace with advancing frontiers and thereby to improve their teaching methods ;

(5) To eliminate from the materials those things that proved relatively ineffective during the trial period ; and

(6) From the knowledge gained to extend the progress made since 1960.

The CHEM study programme begins with an overview of chemistry, emphasizing the atomic-molecular nature of substances. Students are introduced to the periodic table, its uses and how it was actually devised. Then topics of energy, reaction rates, Equilibrium, acids and bases and oxidation reduction are dealt with. Bonding and structural relationships in the various states of matter, together with their chemical reactivity form the next few chapters. The course concludes with a substantial introduction to organic and descriptive chemistry, with frequent application of the principles covered earlier.

Thorough training is given in scientific observation. Excellent textbooks and other supplementary materials are published. The CHEM study films are very popular and have won coveted. awards. Chemical reactions that cannot be done in the class-

room laboratory, are presented in a series of films. Like the laboratory activity, these films are designed to be used not casually, but at specific times during the course.

Physical Science Study Committee (PSSC)

The Physical Science Study Committee's activities were initially centred at the Massachusetts Institute of Technology, but now it has spread throughout America. Not only that, the PSSC text books are being translated into many other European and Asian countries also.

"A central component of the course is the laboratory in which students gain first hand experience in discovering and verifying physical phenomena. The program presents facts that are different from those traditionally included in an elementary physics course, but seeks concepts that are understood and used, not just asserted"[8]. There are many comprehensive sets of means for achieving the purpose of its course—textbooks, laboratory experiments and simplified apparatus, films, achievement tests, books on special topics and a teachers guide for classroom and laboratory activities.

The entire course runs into four parts. Part I deals with the fundamental concepts of time, space and matter, Part II solely with light, Part III with motion and Part IV with electricity and the physics of the atom. Students count, measure, observe, construct and set conceptual models. They are made to realise that physics is not fixed or static, but that it evolves from the enquiries and basic research of scientists. Films also play a vital role in this project.

Science Curriculum Improvement Study (SCIS)

This is a project even now in the experimental stage. It also is financed by the National Science Foundation and the director of the programme is Robert Karplus of California University. The programme is based on fundamental science concepts and a methodology which emphasizes pupil experimentation and observation. The purpose of study is to develop a teaching programme for the primary grades that will increase the scientific literacy of the school population.

The programme believes that many concrete experiences are needed in the early years to enable the child to build a conceptual framework for dealing with later ideas and knowledge. "Special care therefore is taken to acquaint children with specific examples cf objects and organisms, to let them examine natural phenomena and to help them develop skills in manipulating equipment and recording data. Instead of being supplied with correct answers, children are encouraged to think for themselves, to respond creatively to problems presented to them and to arrive at conclusions on the basis of their own observation and interpretation of evidence."[9]

The course outline maintains a hierarchical level of abstractions First level abstractions contain the conceptions of matter and variation in one property among similar objects. The second level deals with the concepts of interaction, relativity and ecosystem and the third level with energy, equilibrium, behaviour, reproduction and evolution of living organisms.

The SCIS has published suitable instructional materials and are very keen about teacher preparation. The success of this programme is not yet evaluated.

Elementary Science Study (ESS)

The Project had been sponsored by about 1960 and is supported by National Science Foundation and Sloan Foundation. Here a number of experimental units are prepared to fulfil a three-fold purpose :

(1) To contribute to a more balanced curriculum by bringing science into the classroom of the early grades ;

(2) To arouse the curiosity of all children, and

(3) To cultivate their desire and capacity for enquiry.

The materials consist of self-contained units each built around a phenomenon the child can observe. ESS materials offer situations conducive to the traditional and rational as well as to the intuitive and more playful learning approach. As questions are raised, experiments are devised to answer the question. No particular style of learning or teaching is called for and lessons are based on the assumption that children make discoveries, formulate hypotheses and design experiments to test these

hypotheses. Published unit materials usually consist of teachers' guides, equipment for children's use, work-sheets to guide investigation and such supplementary learning aids as films, loop-films and information book-lets.

Science—A Process Approach

This Project has been sponsored by about 1963 by the American Association for the Advancement of Science. It concentrates upon the earlier grades of science teaching. "The fundamental assumptions underlying the proposed courses are that science is much more than a simple encyclopedic collection of facts and that children in the primary grades can benefit from acquiring certain basic skills and competencies essential to the learning of science. These competencies have been identified as follows : observation, classification, recognition and use of space time-relations, recognition and use of number and number relations, measurement, communication, inference and prediction. After the 4th grade the emphasis is on the teaching of integrative processes that are interdependent to a certain degree. Children learn to make operational definitions, interpret data, control variables, experiment and formulate hypotheses and models. The expectation is that the ability to use scientific processes will remain after many of the details of science have been forgotten. These competencies are advocated as appropriate for virtually all levels of science education and are not confined to the primary grades".[10]

There are four areas of content suggested, the universe, the structure and reactions of matter, the conservation and transformation of energy and the interaction between living things and their environment, which are designated as appropriate for the first ten years of school and through them scientific behaviour can be achieved.

Conclusion. We have been discussing some recent trends in the curricular changes in U.S.A. But these changes are only at the lower level and at the college levels the traditional curriculum continues. Unless at the higher levels also necessary reorientation is brought about, so as to make it a continuation

of the high school courses, these novel projects have to face many difficulties. Fortunately there are trends of curriculum revision at the College level also.

There are many other, not so popular projects, going on which are not dealt with in this chapter. The University of Illinois Elementary School Science Project and The Minnesota Mathematics and Science Teaching Project (MINNEMAST) are worth mentioning among them.

Summary

Dissatisfied with the existing curriculum a group of new projects are being launched in America. They are sponsored by various Foundations. In science, Biological Sciences Curriculum Study, Chemical Bond Approach Project, Chemical Education Material Study, Physical Science Study Committee, Science Curriculum Improvement Study, Elementary Science Study and Science—A Process Approach are important.

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SECTION III

HOW SCIENCE ?

CHAPTER VII

THE METHOD OF SCIENCE

Science is the process by which men explore the universe and acquire more and more knowledge. In fact, it is not the only path to knowledge. "Supernatural revelation, poetic insight, and feminine intuition are other possible ones. They however, have been found wanting in reliability where and when they are open to such tests as science accepts for itself."[1] Thus science alone has contributed and could contribute to the material welfare of humanity.

Characteristics of scientists. All the achievements of science are the contributions of scientists. Scientists are only ordinary men, but they differ from the latter in certain qualities of mind and heart. Woodburn and Obourn put forward the following as the traits of character which are common in scientists.[2]

(*a*) The scientist has an insatiable curiosity, inquisitiveness and spirit of adventure and a desire to investigate things that capture his curiosity.

(*b*) The scientist is independent in thought, seeks to improve status quo, and is ready to abandon the disproved.

(*c*) He has a fertile inventiveness, a strong imagination, and is creative.

(*d*) The scientist is knowledgeable, enlightened, and informed and possesses sound judgment and prudent foresight.

(*e*) The scientist has high mental energy and is capable of extreme degrees of perseverance.

The scientist is always engaged in a never ending search for truth and has a pleasure in doing so. Indeed many undertake the pursuit of science solely for its own purpose. Dr. Hargobind Khorana after successfully synthesising a gene—the greatest discovery of this century—is reported to have quoted Robert Louis Stevenson—'it is better to travel hopefully than to arrive[3]'.

The scientist is a man with a very broad outlook and is in possession of a disciplined heart.

But these are qualities found among all civilized and thinking human beings to some extent and not merely in scientists. But the scientist puts them to practice and gets the maximum benefit.

Types of scientists. Woodburn and Obourn classify scientists as belonging to three types.[4] The first category of scientists called the 'naturalists' seek knowledge for its own sake. The second group called 'iconoclasts'. rebel against authority, trying to prove the old idols false. The third type of scientists by critical enquiry hope to discover the means of describing, interpreting and perhaps, subduing nature.

Harrison G. Gough has classified research scientists into eight categories.[5]

The 'Zealots' are the first group who are men and women dedicated to research activity with exceptional mathematical skills seeing themselves as driving, indefatigable researchers. They are conscientious, tolerant and serious-minded. They may not get along smoothly with others.

The 'Initiators' come as the second group. They react quickly to research problems and are stimulating to others. They will be good "Team men". They are more free, ambitious, well organised and industrious. They are relatively free of manifest anxiety, worry and nervousness.

The third are 'Diagnosticians'. They are good evaluators. They can diagonose the strong and weak points quickly and have a knack for imposing quick solutions. They do not have strong methodical preferences. They are forceful and self assured in manner and are unselfish and free from self seeking and narcissistic striving.

The next are 'Scholars' who are men with exceptional memory. The are not research perfectionists nor endless seekers for ultimates They are adaptable, well informed, thorough and very dependable.

The 'Artificers' make the fifth group. They give freely of their time. They are aware of their limitations and do not

attempt what they cannot attempt to do. They take poorly formed ideas of others into workable, significant programmes. They are honest, direct, unusually observant and perceptive and can get along well with others.

The 'Estheticians' form the next type. They favour analytical over other modes of thinking. Their interests are far ranging and they become impatient if progress is slow. They are clever and spontaneous, but are undependable and immature, lacking in patience and industry and indifferent about duties and obligations.

The seventh group are constituted by 'Methodologists'. They are vitally interested in methodological issues and in problems of mathematical analysis and conceptualisation. They have little competitive spirit and take a tolerant view of research differences. They are considerate, charitable persons, free from undue ambition.

The 'Independents' come as the last type. They avoid team efforts and dislike administrative details connected with research work. Though having intellectual curiosity, they are not driving, energetic researchmen. They prefer to think in physical and structural models than in analytical and mathematical ways. They are free from worry and self-doubt, but inclined to behave impolitely or abruptly.

A scientist can hardly belong solely to one group. He is a combination of many different types in different proportions.

Assumptions in Science. Science though highly objective and experimental in its nature depends upon many assumptions. Lacey lists these assumptions as follows.[6]

1. *The principle of causality*. A scientist believes that every phenomenon results from a discoverable cause.

2. *Principle of complementarity*. Scientists attempt to incorporate all phenomena into a single, consistent, natural scheme, but they recognise that contradictory generalisations may be necessary to describe different aspects of certain things as they appear to us.

3. *Principle of consistency*. Scientists assume that the behaviour of the universe is not capricious, but is describable in

terms of consistent laws—such that when two sets of conditions are the same, the same consequence may be expected.

4. *Principle of continuous discovery.* Scientists believe that it will be possible to go on learning more and more about the material world and the material universe of which it is a part, until eventually a more complete understanding of the world and universe may be attained.

5. *Principle of dynamism.* Scientists expect nature to show variation and change and to be dynamic rather than static.

6. *Principle of intergradation.* Scientists think in terms of continual, they distrust short boundary lines and expect to find related classes of natural phenomena grading imperceptibly into one another.

7. *Principle of materiality.* Scientists prefer material and mechanical explanations of phenomena rather than those that depend on non-material and supernatural factors.

8. *Principle of objectivity.* Scientists cultivate the ability to examine facts and to suspend judgement on their observations, conclusions and activities.

9. *Principle of Parsimony.* Scientists prefer simple and widely applicable explanations of phenomena. They attempt to reduce their views of the world to as simple terms as possible.

10. *Principle of Practicability.* Scientists expect that in any situation involving competition among units of varying potentialities, those that work best under existing circumstances will tend to survive and perpetuate themselves.

11. *Principle of probability.* Most scientists operate on the premise that certainty is impossible, but they have faith in inductive inferences based on probability, as guides to explanations of natural phenomena.

12. *Principle of relativeness.* Scientists think of the world and of the things in it as sets of relationships established in certain frames of reference. As frames of reference change, so must observed relationships change.

13. *Principle of social limitation.* The social framework in which a scientist operates may determine and limit both the

kinds of problems on which he works and the data which he collects and may also influence his conclusions.

14. *Principle of tentativeness.* A scientist does not regard his generalisations as final, but is willing to modify them, if they are contradicted by new evidence.

15. *Principle of uniformity.* Most scientists believe that the forces now operating in the world have always operated and that the world and the universe we see are the result of the continuous operations of these forces.

These are assumptions in science in detail. But most of the scientific facts, processes and phenomena require only two of the scientific assumptions for their explanation—that there is a reason for everything that happens and that the same cause will always bring about the same results if the conditions are unaltered. The first assumption gives the scientist, faith, hope and encouragement in his process of exploring the universe and the second makes it possible for other scientists to repeat the experiments which have been carried out in order to check the results. Let us see how a phenomenon can be explained with the help of the above two assumptions. Suppose dew is found deposited on the surfaces of some vessels. Applying the first assumption, it must be due to some cause or a combination of causes. Investigation into the matter reveals the causal factor namely the lowering of temperature. When the second assumption is applied to this, whenever the same conditions occur, the same phenomenon should repeat. Therefore whenever there is a lowering of temperature other conditions remaining unaltered there should be dew formation.

The Methods of Science. Systematic scientific research involves two aspects, physical and mental. During the physical process like observation and experiment, the scientist collects necessary data for the solution of the problem and during the mental process he uses many modes of inference like analogy, induction and deduction for the formation and verification of hypotheses.

Physical aspects. As mentioned earlier it is during this stage that all the relevant information for the solution of the problem

is collected. Though termed 'physical aspect', it involves mental processes also to some extent. Since the formulation of hypotheses depends upon the data collected during this stage, it is very important. The scientist has to read, observe, experiment and take note of, during this time. However observation and experiment remain the chief sources of getting data for all material sciences.

(*a*) *Observation.* "To observe something is to direct one's senses and perceptive powers to objects, events or circumstances".[7] Merely looking at or seeing is not observing. Observation is watching things with some purpose or objective. A good observer is described as a person who has learned to use his senses of touch, sight, smell, hearing and taste in an intelligent and alert manner. In science quantitative observations are more useful than mere qualitative observations.

Imperfections of our sense organs may intervene affecting adversely the process of observation. "Even with the closest observations, sometimes we find that anyone of our sense organs is easily deceived and we do not see the whole event. For example, a motor cycle and a bus collide, we find it difficult to keep the facts and inferences distinctly apart".[8]

Observation though an objective process is considerably subjective also. Errors creep in observations, because observers frequently miss things and sometimes invent false observations. "What is observed depends not only upon what there is to be observed but upon the observer and what he has previously observed".[9] Research has shown that our perceptions are influenced by five factors.

1. We tend to perceive what we have learned to perceive.
2. We tend to perceive what we want to perceive.
3. We tend to perceive accurately when our observations fit into a pattern that has meaning.
4. We tend to perceive what others perceive.
5. We can reduce but not entirely prevent perceptual error.[10]

Observations should be accurate, precise and clear and keen observer should be impartial, patient, and should proceed with

great caution. Powers of observation can be cultivated. For this the habit of watching things with an active inquiring mind, objective-based consistent work and an alert mind quite sensitive to unexpected opportunities are necessary.

For successful observation, what is to be observed must fall within the range of human sense organs, must be accessible and not obscured by any distorting medium and observer's sensory equipment must be in good condition. He should have background experience, should be free from personal prejudices and must be cautious of errors creeping in.

Merely by the use of sensory aids, observation won't become experiment. For instance the use of telescope to observe the stars or the microscope to observe some minute particle will not make the observation experimental in nature. Similarly observing some phenomenon of nature in an epitomized form will not make it purely experimental. At the most it is 'artificial observation' though it takes the nature of 'natural experiment'.

(*b*) *Experiment.* Observation of a phenomenon under controlled conditions is an experiment. "Experiments are efforts to observe an event or circumstance under conditions whereas many extraneous factors as possible are eliminated or their probable influence taken into account. These efforts if successful, accumulate bit by bit, evidence for or against an hypothesis. In any pursuit of an adequate description of a phenomenon, experiments proceed through continued elimination of irrelevancies while the investigator attempts to ensure that all essential conditions related to the phenomenon remain and that no newly irrelevant factors are introduced by the sheer mechanics of the experiment".[11]

The validity of experiments rests on the law of consistency of nature *i.e.*, if a phenomenon is observed under certain conditions, then it will repeat and will repeat only again, when the same conditions occur.

Repeated investigations with different samples of the phenomena should be conducted for the greater the number of samples investigated, the more reliable and versatile the generali-

sations would be. Statistical techniques are often used to increase the efficiency of designing, conducting and interpreting experiments.

The experimenter should be very cautious to see that by the introduction of a new device or apparatus, the conditions of experiments are not altered. Sometimes from the combinations of devices, new conditions may emerge or existing conditions may vanish. Special regard must be given to these factors.

The role of science is to establish cause effect relationships. Experiments very much help scientists in this matter. With the previous experience of the investigator, he forms certain hypotheses to test which experiments are to be designed. In forming the hypotheses, the investigator is forced to establish boundaries to his investigation, by declaring certain factors as irrelevant and certain others as relevant. The success of the investigation depends upon the occurrence of the correct answer within the boundaries of investigation. If not new hypotheses enlarging the boundaries are to be selected and new experiments to be designed to verify them. Therefore "students who are beginning their pursuit of science must learn to make their observations with a specific hypothesis in mind, but with at least a part of one eye open lest a glimpse can be caught of fleeting clues to the object of their search—even though these glimpses appear outside the prescribed boundaries of their investigations".[13]

Experiments have many advantages. Because the conditions are within our control we can alter them or apply them at our convenience and make observations. In the case of observation we have to wait, till a particular thing happens. In experiments change of conditions can be effected and the same problem can be attacked from different angles. Again experiments lend themselves for repeated observations.

However objective the experiments be, sometimes subjective elements creep in, thus tampering with the results. Therefore it is better to submit the results of one, for evaluation and criticism, to one's own friends.

Mental aspects. After acquiring the necessary data by physical processes like observation and experimentation, the

scientists think reflectively upon it, to form inferences. Though the physical and mental processes are distinct, sometimes one does not follow the other and at many occasions they go hand in hand. Analysis and Synthesis, Analogous thinking and Induction and Deduction help the scientists in forming hypotheses.

(*a*) *Analysis and Synthesis.* Analytic and synthetic thinking form the basic tools of all forms of scientific inference. In the process of analysis we split or separate things which are together and in synthesis we place together things that are apart. Analytic method proceeds from the unknown to the known, while synthetic method leads from the known to the unkown. In all modes of scientific thought analysis and synthesis are made use of. For example in induction we analyse the common elements in many situations and synthesise them to form hypotheses. In deduction we analyse the implications of a hypothesis and apply them by synthesis to different situations. In analogy two different situations are analysed and common elements synthesised.

(*b*) *Analogy.* It is the most primitive type of inference and it proceeds from particular to particular or from general to general. It can afford suggestions, but cannot establish truths. But it has served as clues to many inventions For example ripples on the surface of water suggested the wave theory of sound and this in its turn helped the formulation of the undulatory theory of light by way of analogical inference. Similarly the atomic structure was suggested by the planetary system. In Biology, the classification of many animals and plants is by way of finding analogous phenomenon.

(*c*) *Induction.* Inductive thinking is very important in science. It proceeds from particular to general and is more advanced than other modes of inference. The generalisations arrived at by way of induction are reasonably valid.

For example,

(1) A, a man, is mortal
B, a man, is mortal
C, a man, is mortal
Therefore all men are mortal.

(2) Sulphuric acid turns blue litmus red.
Hydrochloric acid turns blue litmus red.
Nitric acid turns blue litmus red.
Therefore all acids turn blue litmus red.

(3) Hydrogen gas expands on heating.
Oxygen gas expands on heating.
Carbon dioxide gas expands on heating.
Therefore all gases expand on heating.

(4) By observation, different seeds, distributed by wind, are found to be very light. Therefore by inductive inference we arrive at the conclusion that wind distributed seeds are light.

The process of induction can lead to very absurd conclusions if the investigator is not vigilant. An amusing example is narrated by Prof. D.R. Newth.[13] "A biologist is told that a large island harbours a population of mammals only recently made known to science, which resemble both hares and rabbits and have been christened 'habbits'. He wishes to determine the sex-ratio of the population (defined as the number of males for every one hundred females), but he has reason to believe that the population runs into millions and he consequently proposes to examine a small sample of the population and argue from that. In fact he shoots 100 habbits, all of which satisfy his criteria for femaleness. He is then in a position to make 100 statements of the form :

1. The first habbit I shot was a female.
2. The second habbit I shot was female.
100. The hundredth and last habbit I shot was a female.

These statements are precisely equivalent to the briefer 'I shot exactly 100 habbits all of which proved to be female'. This has little or no scientific interest and does not answer our investigator's question. It can however provoke us to engender more than one series of generalisations of which the following is perhaps the most obvious.

1. All shot habbits are female.
2. All habbits are female.
3. All animals are female.

4. All living things are female.

See how absurd the conclusions are !

(*d*) *Deduction.* Deduction is the most advanced type of inference. It is the way of extending well established laws to particular instances. Thus it proceeds from known to unknown and from general to particular.

For example,

(1) All men are mortal. 'A' is a man and therefore he is mortal.

(2) All Arsenic compounds are poisonous. Arsine is an arsenic compound and therefore must be poisonous.

(3) All flowers effecting pollination with the help of insects have strong smell or colour or both. Jasmine is a flower with strong smell and therefore must be effecting pollination with the help of insects.

The validity of deduction depends upon the versatility of the hypothesis. Therefore it is a test for the hypothesis too. Generally hypotheses are inductively formed and deductively verified. Induction and deduction should go hand in hand and the one without the other is unreliable.

Formation of hypotheses. Hypothesis is only a tentative suggestion for the solution of a problem. It is only a statement that may or may not be true. "A hypothesis is, strictly speaking, a proposition which is put forward for consideration, and concerning the truth or falsity of which nothing is attested until the consideration is completed. It is thus necessarily associated with doubt, but with doubt of a negative rather than a positive kind. With the doubt which consists of a suspense of judgement rather than with the doubt which consists of an inclination to disbelieve".[14]

Hypotheses are accepted only as mental tools which would help to form more substantial explanations. They are to be accepted, modified or totally abandoned in the light of further evidence. "Hypotheses are the scaffolds which are erected in front of a building and removed when the building is completed. They are indispensable to the worker, but we must not mistake the scaffolding for the building.' [15]

Formation of hypotheses is the most important step in scientific research. It is here where the ability of the scientist really reflects. The formation of hypotheses helps the process of investigation very much. They can suggest inconsistencies in thinking and also irrelevancies in the design of experiments. In fact they make experiments more precise, giving the experimenter an idea as to where to look for and what to look for.

The following are characteristics of a good hypothesis. They are :

(*a*) Precise enough to become the solution to a specific problem, yet sufficiently inclusive to yield knowledge that will help the investigator to handle new and related problems.

(*b*) Stated so that it can be tested or verified either immediately or eventually.

(*c*) A clear picture of what the end product of the investigation will be.

(*d*) Logically consistent, free of ambiguity, and contains no tacit or interlocking assumptions.

(*e*) The simplest hypothesis that is adequate to embrace the problems.[16]

It is difficult to explain how a hypothesis is formulated. Analogy, analysis and synthesis, induction and deduction etc. may help an hypothesis to emerge. But they need not result in an hypothesis. A background of knowledge is quite essential. But that alone won't do. We can say that generally hypotheses 'occur' in the mind that is mature enough for that. Sharp intelligence, critical thinking, power of imagination, abundance of past experiences, training in logical thought etc. help forming hypotheses.

There can be many hypotheses formed for the solution of the same problem. Different investigators though having the same experience may propose hypotheses differing widely. All of them heve to be tested and verified before accepting any one of them.

Hypotheses establish cause-effect relationships. When there is only one cause and only one effect acting, then it is

very easy to link between the two and form the cause-effect-relationships. But unfortunately in almost all natural and artificial phenomena, there are a plurality of causes acting, making it quite difficult for one to predict which one is the cause and which the effect. Here Mill's five canons of inference help us.

Though Mill framed five canons of inference, only three of them are most important and the other two can be deduced from them.

The first of these is the 'Method of Agreement.' It states that, if in a group of circumstances in which an event occurs, there is only one factor in common, then that factor may be the cause of the event. For example in a number of different compounds possessing the property of efflorescence, water of crystallisation was found to be common. Then water of crystallisation is causally related to efflorescence. Symbolical example of the law can be given as follows.

$a, b, c, d \rightarrow$ occurrence of an event
$b, c, d, e \rightarrow$ occurrence of the event
$c, d, e, f \rightarrow$ occurrence of the event
$d, e, f, g \rightarrow$ occurrence of the event

Then 'd' being the common factor in all these, is the reason for the phenomenon to occur. But sometimes the method of agreement may lead to very absurd conclusions as well. For example in a number of poisonous drugs, water was found to be common ingredient Then according to this method, the poisonous nature is due to the presence of water !

The second is the 'Method of Difference'. This states that if in a group of circumstances in which an event occurs, there is nothing in common other than the absence of one factor, then that factor is causally related to the event. For example, in a number of surfaces where dew was found deposited, there was nothing in common other than that, they were not at room temperature, but lower. Therefore lowering of temperature is connected causally with dew formation.

To get better results, the method of difference is often combined with the method of agreement to form the 'Joint

Method'. This states that, if in a group of circumstances in which an event occurs, there is only one common factor, whereas in another group of circumstances, in which the event does not occur, there is nothing in common, other than the absence of the above factor, then that factor is causally related to the event. Here the cause-effect relationship established by the method of agreement is tested and verified by the method of difference. Symbolically, the method can be represented as follows.

$a, b, c, d \rightarrow$ occurrence of the event.

$a, b, c \quad \rightarrow$ No occurrence of the event.

Then 'd' is the factor responsible for the event.

The 'Method of Residues' is only slightly different from this. It states that if an event is not found related to all the known factors influencing it, then, it must be due to some residual factor. Many scientific predictions were made possible by this mode of inference. For example, when the path of Uranus was observed, it was found slightly deviating from the orbit calculated. Even when all the interfering factors were strictly verified no explanation could be given for that. Therefore, it was attributed to the influence of another unknown planet. Further observations along the predicted lines resulted in the discovery of Neptune.

The 'Law of Concomitant Variations' comes as the last. It says that if a factor and an event are found varying concomitantly, they are causally related. This law is specially useful with regard to factors that cannot be totally eliminated like, temperature, pressure, gravitation etc. Though they cannot be eliminated, they can be quantitatively changed and their effects studied. If the variation in the intensity of a factor results in a parallel variation of the effect, then this factor is the cause. The variation can be either directly or conversely proportional to the variation in the factor. For example, alteration of temperature of a gas is found to be followed by a change in volume and pressure. Here one can be kept constant (either volume or pressure) and the effect of temperature upon the other studied. This results in Boyle's law and Charles' law.

Symbolically,

$$\frac{a}{b}\ \frac{c}{d}\ \frac{e}{f}\ \frac{f_1}{h_1};$$
$$\frac{a}{b}\ \frac{c}{d}\ \frac{e}{f}\ \frac{g^2}{h^2};$$
$$\frac{a}{b}\ \frac{c}{d}\ \frac{e}{f}\ \frac{g^3}{h^3}$$

'g' and 'h' are concomitantly varying and therefore are causally related.

But Mill's Canons are not fool-proof and a mere mechanical use of it invites inefficiency in design, conduct and interpretation of experiments. The methods do not provide safeguards against

1. Reciprocity of causes and effects.
2. The possibilities of unseen or unimagined factors.
3. The existence of intrinsic, counteracting or catalytic factors, and
4. The composition of plurality of causes combining to produce a new intrinsic effect.

But they afford a general design of enquiry and if used with a good deal of intuition give good results.

"Steps" in scientific thinking. Are there steps in scientific thinking ? The cumulative and self-correcting nature of science is ample evidence to prove that there is no perfect, single, well defined *scientific method*, not to speak of the steps which constitute it. But in the process of arriving at conclusions and forming generalisations, scientists use many methods and these methods are not the monopoly of scientists alone. In this, naturally they have to pass through certain stages of thought. A committee of National Science Teachers' Association prefers the word "modes of scientific thought" and presents the following list.[17]

1. Wanting explanations for phenomena and being predisposed to be bothered by inconsistencies.
2. Observing with discrimination.
3. Classifying observations and other information.
4. Putting all observations into quantitative terms.
5. Pursuing hunches and flashes of insight.

6. Synthesising and modifying explanations.
7. Making and testing predictions based on theory.
8. Communicating

The committee reiterates that they are in no particular order and do not constitute "steps in scientific method."

Scientists attack their problems in a variety of ways. Research scientists though aware of the 'steps' in scientific discovery are found generally not much influenced by it. True scientific research is far from a routine procedure. It requires a lot of inspiration, imagination, insight and sometimes luck too.

Yet, there are some common features in scientific thinking. Karl Pearson arranges them as follows.[18]

1. A problem is stated.
2. Observations relevant to the problem are collected.
3. An hypothesis consistent with the observations is formulated.
4. Predictions of other observable phenomena are deduced from the hypothesis.
5. Occurrence or non-occurrence of the predicted phenomena is observed.
6. The hypothesis is accepted, modified or rejected in accordance with the degree of fulfilment of the prediction.

Let us explain these steps further.

1. *A problem is stated.* The growth of science is through answering problems and at many times, the solution of a problem may pose ten other novel problems justifying the statement, 'when we double the known, we quadruple the unknown'. The problems in scientific research are concerned with the 'What ?' 'How ?' and 'Why ?' In accordance with the nature of the questions posed, the problems in science can be classified as explanatory, predictive and inventory types. The explanaatory problems are answers to the 'why ?' questions and are descriptive in nature. The 'what ?' type of questions form predictive research and 'how ?' type questions yield to inventory research. But this is not a very rigid classification.

The statement of the problem of scientific research should be in clear, simple and unequivocal language. The problem

should be definite and should not be neither too complex nor too simple. It should be defined and the scope of it and limitations specified.

2. *Collection of observations relevant to the problem.* After the problem has been stated and defined, the next step is collection of data relevant to the problem. This is the physical process of science. Data having implications must be collected in detail from all possible sources. Trustworthy scientific data are repeatable *i.e.*, they can be verified by any interested person who repeats the observations under identical conditions.

Two types of errors may creep in during the collection of data.

(1) Mechanical errors caused by instruments we use and mistakes in copying ; and

(2) Errors of judgement caused by personal bias and by the power of suggestion. A scientist should be cautious of all these. However the modern instruments in science are highly objective and of the self-recording type. Like that, photography has mitigated personal bias considerably in describing.

There are however many difficulties in the collection of data by observation and experiment. Both are not always possible. Some phenomena of nature cannot be controlled, altered or eliminated. Many causal relationships stand beyond the scope of experiments. The required scale of experiments may be too huge, or natural conditions cannot be duplicated or perhaps the attempts at control introduce new variables. This delimits the scope of observation and controlled experimentation.

3. *Formation of hypotheses consistent with the observations.* Hypotheses are only tentative solutions to the problems. They are formed by inductive thinking and for the time being they are accepted. A true scientist without any bias will form as many possible hypotheses from as many areas as possible even if the possibilities of some of them holding good are remote.

4. *Prediction of other observable phenomena from the hypotheses.* After the hypotheses have been formed inductively, predictions of other observable phenomena are derived from them deductively. All the implications of the hypotheses are to

be predicted. The acceptance or rejection of a hypothesis depends upon its predictive value.

5. *Observing the occurrence or non-occurrence of the predicted phenomenon.* Further observations are made and experiments are conducted along predicted lines. Sometimes the investigations prove the predictions to be accurate. Sometimes they give negative results. Sometimes exceptions are discovered.

6. *The acceptance, modification or rejection of the hypothesis.* If the observations made in the light of predictions hold good, then that hypothesis is accepted. If only negative answers are given, they are rejected. If exceptions are discovered, then the hypothesis is modified inductively to explain the exceptions after which new predictions are deduced. During the modification process, the hypotheses may broaden in scope and will be found to apply to more situations than originally expected.

As mentioned earlier these are only some stages in scientific thought. They need not be followed in the order given, nor slavishly following these steps, result in discoveries. The only thing is that the thought proc ss of scientists is not haphazard and random, but objective-based and systematic.

Conclusion. Many aspects of the methods of science are discussed in this chapter. But they should not be mistaken as unavoidable pre-requisites for scientific discovery, nor new discoveries and inventions spontaneously emerge by mastering these techniques. H. F. Boulind has strongly criticised too much of importance, being given for scientific method and it seems only legitimate to conclude the chapter with that, "If scientific method means anything, it must presumably mean a method by which new scientific discoveries are made, the method by which science advances......method of finding out the facts and drawing conclusions based on the facts, or alternatively of framing a hypothesis and testing it by experiment. These are respectively the inductive and the deductive methods of procedure. They are undoubtedly part of scientific method, but by no means the whole. If they are the whole, progress in science would be far simpler : any one with reasonable intelligence and knowledge could apply the principles of induction or deduction and so arrive automatically at new results and great

discoveries. No Lavoisier would be required to discover oxygen and the nature of combustion, no Michelson would be required to discover the nature of cosmic rays; any one of us could apply the rules and get the results, without being geniuses" [19]

Summary

There are many types of scientists. Science is based on many assumptions. The mental aspect and the physical aspect constitute the method of science. In the physical process, the scientist acquires data necessary for the solution of a problem. Observation and experiments are the main methods of acquiring data in science. The mental aspect is concerned with the interpretation of data and arriving at conclusions. Analysis and synthesis, induction and deduction, analogous thinking etc. help the formation of hypotheses. There are no prescribed 'steps' in scientific thought. But there are certain stages through which the mind passes before arriving at conclusions.

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CHAPTER VIII

THE PSYCHOLOGY OF LEARNING AND TEACHING SCIENCE

Introduction. Teaching is often described both as an art and as a science. But to what extent it is an art and to what extent it is a science has not been stipulated One thing is sure that good science teaching is not a mere chance ; it is the result of effective thinking, good planning, and sufficient early preparation. To do all these, the teacher should be well versed with the psychology of learning by children. It is here that the modern science education deviates from the traditional techniques which always minimised rational and empirical approaches and maximised intuitionism and authoritarianism.

What is learning ? Learning is the process by which we profit from past experiences. McConnell has defined learning as "the modification of behaviour through experience and training."[1] According to Skinner learning "is a process of progressive behaviour adaptation"[2]. Much research has been done in the field of learning, but the general nature of it still remains a puzzle.

Principles of learning

Based on the various schools of thought on learning, there are so many laws formulated. But all these remind us that the psychology of learning is only in its developing stage and that the laws of learning are only in the process of being formulated and they must be taken only as working principles.

Hullfish and Smith have reported five principles of learning.[3]

1. The learner is motivated—when he has some stake in the activity.

2. The learning is geared to the learner's level—when it is compatible with the learner's physical and intellectual ability.

3. The learning is patterned—when the learner can see meaningful relationships between the activity and the goal.

4. The learning is evaluated—when the learner has some way of knowing what progress he is making.

5. The learning is integrated with personal-social development—when the learner experiences satisfactory growth and adjustment.

John. S. Richardson has formulated principles of the learner and the process of learning.[4]

1. Learning results from the active involvement of the learner.
2. Learning begins with the learner's present achievement.
3. Motivation increases the effectiveness of learning.
4. Learning occurs through various channels
5. The meanings of words and other symbols are based on experience.
6. The total organism learns in response to the total situation.
7. Learning varies with the individual differences in need and ability

These psychological principles of learning influence all levels and areas of educational process. They are applicable to all subjects too. A discussion on the various implications of these principles seems useful.

1. *Learning results from the active involvement of the learner.* Maximum learning takes place, when the whole learner is involved in the process of learning. For this the learner should be aware of the goals of learning and must have belief in it. He must be convinced of its need and necessity.

'Learning by doing' and 'learning by living' are the methodological implications of this principle. Often teachers resort to mere telling of facts and principles where first hand experiences must have been essential. But that does not mean that telling is forbidden. When there is scope for providing first hand experience teachers should not resort to mere telling. Due to varying reasons on many occasions of teaching, telling becomes inevitable. There are considerations of time, finance

etc., which prevent direct experiences from being provided at all occasions. "However, granting tnat there is a place for the act of telling in the process of teaching, the good science teacher does not lose sight of the fact that boys and girls must have a broad range of experiences as they learn".[5]

Providing experiences is not so expensive a process. The community offers many resources appropriate for teaching science. Some of them are listed below.[6]

1. Museums, zoological parks, and botanical gardens.
2. Chemical and other industrial plants.
3. Airports.
4. Telephone buildings, radio stations and power plants.
5. Engineering projects.
6. Weather bureaus.
7. Bird sanctuaries.
8. Near-by farms, gardens, vacant lots and woods.
9. Mines and quarries.
10. Lake or ocean shore lines.
11. Caves, gaps and other interesting natural phenomena.
12. Ponds, lakes, streams and bogs.
13. Observatories and planetariums.
14. Field trips to observe agents of weathering and erosion at work.
15. Green houses.
16. Stores and markets.
17. Exhibits, garden clubs and flower shows.
18. Departments of health and sanitation.
19. Junk yards.
20. The constellations and other heavenly bodies visible to the naked eye at night.
21. Water purification plant.
22. Milk pasteurization plant.

The science teacher is most advantageously placed because of the richness of the environment in scientific materials. The real things of the world which form the materials of science are so readily and abundantly available for providing first hand experience.

Experiences can also be provided in plenty from the laboratory. But the laboratory experiences to be meaningful should be problem oriented. Otherwise they will become mere exercises. Demonstrations if done in the true spirit of it will be equivalent to first hand experiences. Again the audio visual materials provide with a multiplicity of experiences. The organisation of science clubs, science museums, science fairs, science exhibitions etc., are also highly rich as far as experience value is concerned.

The teacher to be sincere to his profession must resort to experience centred education which actively involves the whole learner.

2. *Learning begins with the learner's present achievement.* The learner's mind is not a mere vacuum. It has at its credit abundance of previous direct and vicarious experiences which it has accumulated during its past life. Learning to be effective must link the new knowledge with the past experience. It creates interest. The satisfactions of past achievements result in the drive for further achievements.

Therefore for teaching to be more effective, the teacher should be well aware of the past experiences, the students have had and their present interest and inclinations. The teacher should understand his pupils before starting to teach. He must be aware of what they know, what they want to know and what they can do. The previous scientific experiences of the child and his knowledge in general should form the foundation upon which the future course of instruction is based. It will be much useful if the teacher keeps a personal record for each of his pupils which reveals to him the present status of the student, his intellectual capacity, family background, achievements, anecdotal records, health history and the like. The teacher must also be aware of the experiences of the child in extra-curricular activities, his scientific interests, what he likes to learn and what he needs to learn. The teacher should be formally and informally in constant touch with his pupils so that he can understand the changes in their interests and aptitudes and adapt his teaching accordingly.

3. *Motivation increases the effectiveness of teaching.* The child learns effectively when he is motivated to learn. Motivation is the result of perception and adoption of purpose. It is one of the most fundamental aspects of teaching learning process. To motivate his students properly, the teacher has to understand his pupils and their needs and interests. However motivation cannot be forced upon pupils. "The history of education is a long record of the failure of efforts to control pupil behaviour by external forces. Motivation does not come from the outside, but from within. A person's behaviour is determined by himself as a response to needs that he feels within himself".[7]

Motivation can be either intrinsic or extrinsic. Keeping the pupils informed of their results, rewards and punishments, praise and blame, rivalry etc., are accepted techniques of motivating pupils. It is a continuous process which starts with education and lasts throughout the course. Lacey offers the following suggestions regarding the techniques of motivation to teachers of science.[8]

1. Exhibit as much enthusiasm for your work as possible—it's contageous.

2. Provide as pleasant an atmosphere as possible in your classes.

3. Always try to teach within the experience range of the class. You must speak on the students level, or they will not understand you.

4. Remember, teaching is much more than telling.

5. Let pupils take as much responsibility for class procedures as their maturity and readiness will allow ; some might be more proficient than you on certain aspects of the subject.

6. Provide opportunities for pupils to do projects and independent work, scientists are developed that way.

7. Take opportunities to be informal with pupils when occasions allow ; few pupils appreciate "fuddy-duddies".

8. Sponsor a science club and give students maximum opportunity to run it, excellent individual and group work often comes from clubs.

In addition to these, providing occasions for students to demonstrate to the class, to report to the class on field trips of scientific interest, displaying their achievements and also giving provisions for students to take responsibility for the resources of the science rooms and to keep records of their accomplishments in science help very much.

The same technique of motivation will not prove effective with all students. The effectiveness of a technique varies from pupil to pupil. The technique should be carefully chosen, jodiciously planned and appropriately used.

4. *Learning occurs through various channels.* Individual differences influence the learning process. Different pupils learn differently. In fact the same pupil acquires knowledge from different sources in different ways. There is no one best method as such either for teaching or for learning science.

This is a very important point that the teachers are to bear in mind. Many teachers get satisfied merely by providing only one sort of learning experience. However effective this one learning experience be, it is not a substitute for a multiple approach. There are audiles, visiles and motiles among students. For all of them to get the benefit, as many different learning experiences as possible must be provided. In this regard the science teacher is very advantageously placed. He has a number of avenues that can be used in teaching like photographic materials, printed materials, maps, charts, films and film strips, models, specimens, mock-ups, dioramas etc., and the wide nature which is so natural a teaching aid with abundance of resources. Again there is the laboratory, the monopoly of the science teacher.

Sometimes the teachers may get confused because of the variety and multiplicity of teaching aids as to discriminate between them and select the most appropriate and suitable one. Too much of experiences, of course, creates confusion. The needs of different students, their intelligence level, aptitudes and interests should be studied thoroughly before providing the learning experience.

5. *The meanings of words and other symbols are based on experience.* The meanings of words are formed in relation to past experiences of the child. No past experience means no correct concept at all. For example, we cannot explain the colour of a rose to persons blind from birth. Therefore in teaching science, as in any other subject, as much correlation should be made as possible with the previous experiences of the child.

Pupils find meanings in relationships and generalisations. They develop meaning through classification. "A significant aspect of meaning in science for the scondary-school student is found as cause and effect, or the conditions antecedent to a given event. Such meanings are often explanations which show or describe, operationally, the relation of a given condition, effect or event, to other known facts, principles, physical conditions, or substances. Perception of the principles of heredity or the bases for weather phenomena are examples of such meaning".[9]

The developmnets of proper meanings and concepts are sometimes hindered by past experiences. Many scientific terms are used in a different sense and meaning than their common use. For example the concepts of 'work' and 'force' in science are different from their ordinary use. Work is said to be done and force is considered to operate only when certain conditions are fulfilled. Not so in the ordinary use. Here to develop the proper concept and meaning requires both a negative and positive process. The teachers have to erase from the minds of the students, the common meaning and then develop the scientific meaning.

Science is highly symbolic in its nature. Many of the symbolic representations confuse the learning process, unless the teacher is cautious to provide with some sort of basic experiences and perception of relationships. "It is quite possible to manipulate chemical symbols with accuracy, but without understanding. The completion and balancing of the chemical equation for the neutralization reaction of hydrogen chloride and sodium hydroxide can be nearly meaningless to the

students. The balancing of the equation can take on meaning as the student solves a problem by neutralising a base with an acid. But this must be his problem, not one in word form in a work book, that he is expected to adopt. It may have a practical origin—to determine the acidity of soil—or a theoretical source—how to explain the nature of a salt."[10]

6. *The total organism learns in reponse to the total situation.* When the child is involved in learning, he is involved, not only in what is being learned, but in the whole environment. Even things which we consider as unimportant and insignificant may sustain his attention and thus affect learning. Therefore learning experience for the child is the whole learning situation. That means that not only the content that he studies, but the apparatus, the reading material, the teaching aids, the physical features of the classroom, his classmates—all make their impact upon him simultaneously.

Similarly not only the mind of student, but his whole 'person' is involved in learning. He is influenced by health conditions, the food he has taken, his home atmosphere, the teaching method, his emotional set up and all that. While the student learns, he learns, things in relation to all those. It is not merely the mind of the students which learns and masters the content taught, but it is the whole 'person' of the student which reacts with the learning situations. He learns as a total organism.

Suppose the student has to learn the laboratory preparation of a gas. He masters the methods of preparation and its properties. But if the gas has an unpleasant smell also, the child may develop psychological reactions. If the teacher is not taking note of these psychological repurcussions of the child, unpredictable consequences may follow. Perhaps the child may develop a disinterest or aversion for the whole subject. But a little intellectualisation of the fact that some substances do not have a pleasant odour may avoid such emotional reaction.

7. *Learning varies with individual differences in need and ability.* The psychologising of education has resulted in the

individualisation of instruction. But how far the individualisation has come to effect is a problem to be investigated. Even in economically much advanced countries, because of heavy financial burdens of the scheme, the individualisation has not taken place to the desirable extent, not to speak of the under-developed countries.

Two students are never alike. Their intelligence, previous experiences, social backgrounds, ambitions, interests all vary widely. As learning is being influenced by all these factors, different children learn differently in the same set up. This is a factor which has not influenced our educational system even to the least extent. We have common courses, common class-rooms, common textbooks and other instructional materials which all students have to master invariably. This unhappy state of affairs hinders the progress of exceptional pupils and neglects the cause of the retarded students. "The greatest challenge in education to-day is the development of means whereby each young person can progress at his maximum rate as far as he is able to go. Completely individualised instruction is too expensive. Mass instruction techniques, though providing equal schooling opportunities are unjust to pupils who should progress more rapidly or more slowly or in other directions"[11]

Though it is not possible to individualise instruction totally, the science teacher can take certain steps which may cater to individual differences. Richardson offers three suggestions in this regard.[12]

(*a*) The science teacher can draw upon the multitude of first hand experiences that are available. These vary in difficulty as well as the interest that they evoke in the student.

(*b*) The wide range of teaching materials for science—charts, displays, motion pictures, mock-ups multiplies the opportunities to meet individual needs.

(*c*) In the reading material available can be found levels of complexity to provide for wide differences in ability and approaches that stimulate varying interests.

The teacher should give adequate care to the children of different achievement group. His methods should be so elastic as to suit the above average, average and below average group of students simultaneously. For the above average it should unfold the areas of further activities, for the large average group, it should give a sense of confidence and for the below average it should be a strong source of stimulation. With the short span of time available for him, he should attempt for maximum individual achievement regardless of ability.

Apart from the principles of learning disscused above, Lacey puts forward some guiding suggestions which are found much helpful for teachers.[13] Though some of them generally overlap with the principles already discussed, they are quoted here for their practical value for science teachers.

1. Pupils learn within the context of their previous experience.

2. Pupils need an emotionally and intellectually stimulating environment.

3. Pupils learn better when they feel secure with and have respect for teachers.

4. Pupils need multiple, concrete, first hand experiences as bases for concept formation.

5. Pupils need to see whole stimulations as well as the various parts in relation to the whole.

6. Pupils should be engaged in activities calling for critical thinking and problem solving.

7. Learning experiences should be planted in a meaningful, sequential pattern.

8. Every learning activity should have a definite objective—which has purpose for the pupil.

9. Pupils should share actively in selecting problems and goals which have meaning to them.

10. Provision must be made for individual differences in abilities, interests and needs.

11. Meaningful practice should reinforce sensory experiences.

12. The teacher must plan as carefully for attitudes and appreciations as for knowledge and skills.

13. Learning should lead to a purposeful action related to it.

14. Learning gained in the classroom should transfer readily to out-of-school situations.

15. Pupils should participate in the evaluation of their learning experiences.

16. Pupils should receive emotional and intellectual satisfaction and a sense of achievement from their learning experiences.

Principles of teaching

Just as in the case of learning, there are no definite laws which control teaching. If there were set laws, then anyone who masters these laws might have become good teachers. Unfortunately it is not so. The qualities of good teaching are difficult to be identified. A good percentage of teaching process still remains an art and to make any laws from this sphere is bound to fail. But teaching is partially a science also involving a lot of skills and techniques of its own and these skills and techniques can be improved by training. It is here that certain broad principles are applicable. They are so broad that they form only certain guiding statements. Richardson has suggested five such guiding principles.[14]

1. Teaching and learning cannot be separated.
2. Effective teaching reflects the teacher's objectives.
3. Careful planning is essential to effective teaching.
4. Effective teaching is essentially good guidance.
5. Good teaching is a deliberate, time-consuming task.

To make the meanings of these statements explicit, a discussion based upon them seems essential.

1. *Teaching and learning cannot be separated*: The meaning of this is embedded in the statement that 'the teacher has not taught until the pupils have learnt'. Learning is the corresponding process of teaching. In fact it forms the evaluation for the teaching process. A sincere teacher evaluates his students continuously not only to plan further course of action.

but also to assess the quality of his teaching. He should make improvements based upon these assessments.

A good teacher is a good learner also. The enthusiasm of the teacher in learning reflects upon his pupils and they are also induced to learn. Apart from his regular studies, the teacher has much to learn from his own students during the course of his interaction with them. If he can establish good interpersonal relationship with his pupils, it will have a good incentive for his pupils to learn. The old authoritarian appraoch is lost and he becomes a democrat. "Further, as the teacher shows his own enthusiasm for learning he steps down from the chair of authority and becomes another worker, a human being with his own aspirations and with his own problems to be solved. As the teacher and his students work together, they develop mutual confidence."[15] The experience that the teacher gains in working with the group helps him to stand in good stead in future.

2. *Effective teaching reflects the teacher's objectives* : Teaching is a purposeful activity directed towards the realisation of certain goals. The major objectives of teaching science are discussed in the second chapter of first section. Unfortunately, with many teachers of science, even now the major objective remains the acquisition of knowledge in the subject. Other higher objectives like Application, Skill, Interests, Appreciations etc. are forgotten. But whatever be the objective, it should reflect upon his teaching. Indeed teaching is planned and oriented for the realisation of the objective. For example, if imparting of knowledge alone is the objective, telling is the best method for it. But for the realisation of higher objectives, the Problem method, Project method etc. have to be accepted.

Objective-based teaching and evaluation has become the trend of the day. In some foreign countries it has already been accepted, but in India some States alone have sponsored it. The National Council of Educational Research and Training and also the various State Institutes of Education give inservice training for teachers on a large scale on objective based

teaching and evaluation. From an approach it seems to have become a method by itself, with certain specific features of its own.

Teachers should know the immediate and long range objectives. Immediate specific objectives are for the days lesson and long range objectives for the whole course. The method he selects for teaching should be in agreement with the objectives to be achieved. Indeed in every activity of the teacher the objectives should reflect.

3. *Careful planning is essential to effective teaching* : Planning has become a way of life nowadays. It is nothing other than applied common sense. We plan all walks of our life. Really, no activity can be successful without sufficient, early planning. Some scientific discoveries might have been the results of fortunate accidents. But they are only exceptions.

Just as in all other fields, good teaching also requires sufficient planning. The teacher should take into consideration, the capacity of the students, the duration of the course, and the resources available, before making early plans. Planning should be made at different levels, for the day's lesson, for the unit, for the year and for the course in toto. Plans should be flexible, specific and realistic. Planning is never complete, it is a process and should continue throughout the teaching procedure.

Students were kept aloof from the planning process in the traditional methods of teaching. This is unpsychological since they tend to become foreigners in their own classrooms because of this. If planning is made with the co-operation of the students too, thus making them active participants in all teaching activities, it gives them a sense of emotional involvement in studies which catalyses learning very much. They are convinced of the objectives to be realised and therefore all the activities become meaningful and purposeful for them.

5. *Effective teaching is essentially good guidance* : 'The teacher should not teach, but only help to learn' is the modern

slogan about teaching. To help to learn means guiding the activities of the student. When the teachers resort to teaching, students become passive listeners whereas when guidance alone is given for learning they become active participants, in the learning process. Any learning activity without the active participation of the students will not be effective. Therefore the role of the science teacher also is behind the curtains. He is only a friend, philosopher and guide offering help whenever it is necessary and not the traditional, dominating, authoritarian master directing the activities of the students. He as a good child psychologist provides all the necessary stimulating learning experiences and tries to abstain from unnecessary intervention. The child, in his turn, interacts with these learning experiences and acquires knowledge thereby.

The science teacher can act as the counsellor too. Counselling cannot be totally isolated from the teaching process. The teachers, who can understand children more easily than others, can act as efficient counsellors. Sometimes the process is reverse—good guidance and counselling helps the teacher in understanding his students in a better way.

6. *Good teaching is a deliberate, time consuming task* : Scientific knowledge is so wide and deep that the inclusion of the whole of it in any curriculum is unpracticable. Even by selection all aspects of it cannot be properly represented. It takes a lot of time even to cover one or two minor areas of science, the mastery of the whole of science remaining an impossibility in a life time.

Teacher should not be highly ambitious in the learning of his students for sometimes he may be desperated. If there is overcrowding of syllabus, it tends to confuse and frustrate students. But the students should get continuous motivation and inspiration to achieve fully well. "The teacher should recognise however, that time is a necessary investment if students are to achieve satisfactorily. The content of science in many respects requires a new language, almost a foreign language, based on array of ideas, concepts, generalisations and facts that are unfamiliar and difficult. All students need time to

learn to use this new language and these new ideas intelligently."[16]

The realisation of the higher objectives of teaching science is a time consuming process. Knowledge can be acquired and understading can be developed in a comparatively short period. But development of scientific mindedness—interests, appreciations and attitudes—is notably slow.

Conclusion : A knowledge of both the principles of teaching and learning science helps the teachers of science in all their activities. But blindly following them is not good. He should become a master of these principles and at the same time should formulate his own working principles which should guide him throughout his career. Slavishly sticking on to any principle, however good it be, can make the class lifeless and stereotyped. But following the spirit of these principles is essential for good teaching.

Summary

Learning is the process by which we profit from past experiences. There are no strict laws about learning, but certain working principles have been formulated. Just like learning, teaching also cannot follow any strict law, it partly being an art also. But there are certain guiding principles about teaching. A knowledge of these principles about teaching and learning may help the teacher to stand in good stead. But he should not slavishly follow any principle. He should formulate working principles of his own.

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CHAPTER IX

THE PHILOSOPHY OF METHODS

All aspects of teaching are directly and indirectly being influenced by philosophical and sociological factors. The methodology of teaching is no exemption from this, but it is only indirectly influenced by these factors. First, the aims of education are oriented to be in harmony with the philosophy of the society, which in their turn rather prescribe the curriculum, methods, etc.

The objectives of teaching science request the teacher to select only suitable methods for their realisation. The teacher's methods thus reflect his philosophy towards science teaching. It has in fact evolved because of his faith in the potentialities of science. "A science teacher's philosophy is a statement of faith in the importance of his work. In his philosophy, he recognises certain potentialities of the science programme to meet the needs of young people."[1] As the philosophy of different science teachers varies, their methods also are bound to vary. But because all of them are equally concerned with the maximum, possible development of the student's personality, and are dedicated to the cause of science, there are certain broad principles which are found common in their course of procedure.

These common principles took the form of certain maxims of teaching methods in the traditional educational system. These maxims represented the philosophy behind all teaching methods. Even though they are comparatively old, their spirit is new and therefore a discussion on them may be useful for teachers.

1 *Proceed from known to unknown*: Children when they come to the school possess abundance of previous

experience. They are not mere clean slates. They are much experienced by way of their interaction with their parents, siblings, friends, peer groups, and their immediate environment had already made certain valuable impacts upon them, which the science teacher should exploit to the maximum extent. This previous experience is of special advantage to the science teacher because his subject matter is the environment of the child itself. Learning will be effective, impressive and meaningful to the child, if sufficient correlation is made with the previous experience of the child. It is interesting for him. To be interested, means to learn spontaneously. "The primary function of education is that of fostering interest. Given interest, at any level of ability learning follows."[2]

For example, if the Principle of Archimedes is to be taught in the class, an unresourceful teacher can very well narrate the principle, ask the students to recite and thus finish the portions. But this will be the most unpsychological type of approach a teacher can ever make. Students in their daily life must have had a lot of previous experiences which correspond to the Principle of Archimedes. They might have taken a bath in a pond, have tried to lift a stone while under water, have drawn a bucket of water from the well and might have felt the apparent loss of weight in all those cases. But they don't know how much loss was there. The teacher while starting the lesson can motivate the students by making reference to these experiences stated above and thus can create problematic situations. Once the problem is set, the students are excited and they show greater interest in the teaching-learning process.

Many of our teachers in all subjects do follow this maxim while planning and delivering lessons. During the motivational stage of the lesson they call for the previous knowledge corresponding to the lessons. But unfortunately in the hands of poor teachers this has degenerated into a stereotyped and monotonous step proceeding in the form of some set formulas. There are many notorious examples of these stereotyped preparation techniques.

2. *Proceed from easy to difficult*: Whatever may be the steps the educators and teachers take for the psychologising of education and for making the learning process as smooth as possible, it still remains somewhat a tedious task for the students especially so in the Indian conditions. It is partly because of the purely logical treatment of the syllabus. Purely logical treatment is quite unpsychological for the child.

The intelligence of the students is only in the developing stage when they are admitted in the schools. If they are overburdened with complicated principles and concepts from the very beginning, they get frustrated and soon develop an aversion for the subject altogether. If comparatively easier portions are taught first, this does not however happen. But the teacher should be very much careful in selecting the easier portions first. What is easier for him need not be easier for his pupils. Similarly the psychological treatment should not also very much dislocate the logical growth of the subject.

However the science teachers of India are helpless in this regard. The curriculum and the syllabus are framed from the top and enforced upon the teachers. Even the slightest deviation from it is not tolerated by the unintelligent administration. The teachers are compelled to teach what is there in the text book in the same sequence and order. Yet the teachers should do what is possible in the matter.

(3) *Proceed from psychological to the logical.* Learning is a highly psychological process. Children have a psychology of their own. They think and act differently than the adults. The logic of the subject becomes sometimes indigestible for him. The child needs the mastery of simple facts before proceeding to difficult ones. Sometimes the child need may go against the logic of the subject. For example, the logical treatment insists on the inclusion of 'oxygen' and 'hydrogen', before water, whereas for the child it is quite unpsychological for water is more familiar, easy and simple for him and therefore it should precede oxygen and hydrogen.

One thing is important here. Psychological treatment need not last throughout the course. At the higher stages logical treatment is advisable. Otherwise the spirit and romance of the whole subject will be lost.

The arrangement of the syllabus either in the logical order or according to child psychology is chiefly the concern of curriculum makers and the teacher, at present, has nothing to do with it. Yet with the limited scope, he must try to give a psychological presentation.

4. *Proceed from concrete to abstract.* Children want concrete experiences for effective learning. Especially at the lower stages, they are incapable of abstract thinking. This is a fact which throws much responsibilities upon the shoulders of teacher. He must find and provide concrete experiences for the students to make them understand the abstract ideas represented in the text books. For example, children cannot easily understand simple additions and multiplications of numbers. Addition of five and five is difficult for him at the initial stages. But if two groups of five pebbles each are provided and he is asked to add them, it becomes concrete experience and therefore easy and meaningful for him. At the higher stages also providing concrete experiences helps the development of accurate concepts. If direct experiences cannot be provided easily, the teacher can switch over to indirect experiences by way of exhibiting charts, maps, dioramas, films, etc. They make learning interesting and develop proper concepts in children.

5. *Proceed from particular to general.* Teaching science is not merely for the acquisition of knowledge. Science is equally a process too. This means that there should be sufficient mental training for scientific thinking. For this training in inductive and deductive reasoning becomes inevitable. Inductive thinking means arriving at a generalisation from so many particular examples and deduction means extending a general statement to a particular example. Training in inductive, deductive and analogical thinking is quite essential for the realisation of the higher objectives of teaching science. But before generalising a phenomenon, so many particular examples should be

provided. Similarly, the generalisation arrived at by induction should be verified by deduction. Inductive thinking has importance at the lower stages of learning and deductive thinking at the higher stages.

These five maxims are only very broad principles behind teaching methods. There is no harm, if, at one stage, the teacher to make instruction more effective, deviates from any one of these principles for the time being. Teaching being an art also, cannot follow any specific rule. But his methods should not always proceed contradictory to these maxims always.

Apart from these maxims of methods, there are certain modern suggestive principles also which help much the teaching procedure. As they form the foundations of all modern teaching methods, they are also included here.

1. *The pupils should be led to discover for themselves.* The spirit of science is discovery. Fortunately, children have a great thirst for discovering things for themselves. The science teacher can exploit this most profitably. But this does not mean that the student is to be left unguided. Learning materials and necessary suggestions need be given. But the final discovery should come from the brains of the child itself.

The discovery approach helps the students in many ways. The feeling that he has discovered something develops a confidence in him about his own capacities which is a good incentive for further learning. Secondly, the knowledge that is gained through discovery is retained for a prolonged period of time. Though the discovery approach is a time consuming process, it helps the realisation of the higher objectives of teaching science and the development of scientific mindedness in an easier way.

2. *They should be encouraged to learn by doing something.* Children are very active and dynamic always. They are always interested in doing something and derive much pleasure in doing so. Conducting an experiment in the laboratory, making an observation about the growth and development of a plant or organism, undertaking a project, etc., are highly interesting and

informative for the students. The knowledge acquired through these processes are highly realistic and practical.

3. *Children should be exopsed to as many first hand or direct experiences as possible.* Children develop concepts and arrive at generalisations from many different ways. Therefore the teacher should provide numerous opportunities for children to explore, inquire, manipulate etc. As many direct experiences should be provided to the children as possible. But when direct experiences cannot be provided, indirect experiences are enough. "......first hand experience is the most valuable way of learning for little children. But it is not always possible to experience things which are far away. Moreover a real thing may be too complex, too big, or too small for study. In such circumstances we resort to models or some other aids."[3]

Piaget and his associates think that the children's ability to deal with the broad concepts of space, time, matter and causality depends upon a type of thinking that slowly develops from the direct sensory experiences of children.[4] "Sensory motor experiences such as manipulation help the child construct and reconstruct percepts, concepts, generalisations, and other processes of thinking. This can be done on any level.

1. A young child believes a ball of clay changes weight, when shape is changed. By changing shapes of clay he can experience that a long, thick, clay form can be the same weight as a short thick one.

2. By trial and error primary grade children work out the relationships of weight and distance from the fulcrum on a teeter-totter. Later verbalisation of the principle of inverse ratio of weight and distance will be possible.

3. The sixth grader who builds models of atoms with coloured balls representing electrons, protons and neutrons "sees" electrons gained and lost. Each direct sensory activity then gives more fibres to the child upon which to weave the fabric of perception and thinking."[5]

4. *Instructional techniques must be flexible.* However thoroughly a teaching plan is prepared, the teacher should not be slave to it. Things which may upset even the best made plans can happen in the classrooms. "The resourceful teacher will conceive of a plan for a lesson as only a guide within broad limits and will be alert to lay hold of any unique situation that may arise spontaneously in the classroom and which may prove more effective than the plan previously made."[6] A rigid programme makes both teaching and learning an uninspiring and monotonous affair. Both the teacher and the student should enjoy an air of freedom which is quite essential for educational growth.

5. *Teaching should have sufficient correlation with other subjects and daily experiences of students.* Different subjects are only the results of artificial classifications. They, if imparted in watertight compartments, won't create much interest in children. It won't also be much meaningful for him. To rectify all these defects subjects should be presented bringing out their mutual relationship. There are two types of correlation—incidental and systematic. The latter is the responsibility of the curriculum makers. But incidental correlation is the responsibility of the teacher. For this he should be more or less versatile—knowing something of everything. Above all the whole course in science should be correlated to the daily environmental problems of the child.

Summary

All methods of teaching have philosophies of their own from which they had their origin. Though philosophies differ, there are certain common aspects which underlie all of them. The traditional maxims of teaching and some modern principles of comparatively recent methods represent the philosophy of methods.

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CHAPTER X

METHODS OF TEACHING—CLASSIFICATION

There are a number of methods which are advocated for teaching science. All methods have something to recommend it. But any method will be successful only in the hands of good teachers. A man may be a good scholar, may be highly resourceful; but he need not be a good teacher. Teaching is an art and just as any other art it requires some skills for its success. "Some teachers from the start have a "flair" for teaching, they possess some subtle ability to awaken the interest and gain the confidence of their pupils, others have less initial advantages. None are so naturally gifted that they cannot benefit from a study of teaching methods; few are so naturally unsuited that they cannot improve their skill by thinking about how best to teach."[1]

Though there are many methods of teaching there is no one best method for teaching science. Each teacher should be resourceful enough to adopt all methods so as to produce best results. Various methods should supplement and complement one another. The sole dependence on one method makes teaching mechanical and monotonous. Teachers should be masters of all methods and slaves of none.

Classifications of methods

There are many ways of classifying methods. One way of classification puts them under five heads.[2]

1. Techniques for developing functional understandings.
2. Techniques for developing scientific attitudes.
3. Techniques for developing appreciations.
4. Techniques for developing interests.
5. Techniques for developing skills of problem solving.

Obviously the objectives that the method will realise are taken as the basis for classification.

Miller and Blaydes after analysing and synthesizing all the methods put them only as four.

1. Text book recitation method.
2. The laboratory method.
3. The demonstration discussion method.
4. The problem project method.

They add, "These four groups include the elements of nearly all other methods which are, in most cases, modifications or combinations of them."[3]

Anyhow the traditional way of classifying methods puts them under two approaches.

1. The authoritarian approach (Teacher-assertive methods) and 2. The discovery approach (Child-assertive methods). The basis for the classification evidently is the role of the teacher and the taught in the teaching process. Under the authoritarian approach come Lecture method, Lecture-demonstration method, the Historical and Biographical methods, and the comparatively modern team teaching. In the discovery approach come the Laboratory-experimental method, Developmental method, Heuristic method, Problem method, Dalton plan, Winnetka plan, Project method, Supervised study, Programmed learning, etc.

The discussion of these methods in detail is undertaken in the chapters that follow. It would reveal that these methods are not mutually exclusive. Many of them broadly overlap. Some run parallel on many points. The only difference is that one method will stress on one aspect while not neglecting the other desirable factors of other methods.

These methods are not the monopoly of science teachers. They are common to all subjects. But the science teacher has scope for practising all of them or synthesize all of them and form his own methods. The spirit of any method is good, but the results of following any one method blindly are doubtful. Again it largely depends upon the teacher

whether a good method is really good or a bad method is really bad.

One point more. For the teaching of science as in the case of any other subject the child-assertive methods are better. In fact the evolution of methods in teaching science has always been in this direction. The emphasis now is on 'learning and not on teaching'. Therefore increasing activity and participation on the part of the students, which only may help them to discover, are always welcomed.

Summary

There are a number of methods for teaching science. They can be generally classified as teacher-assertive methods and child-assertive methods. In teacher-assertive methods, teachers are dominant and in child-assertive methods, children assume importance. These methods are not mutually exclusive. The success of any method depends upon the teacher.

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CHAPTER XI

AUTHORITARIAN APPROACH AND TEACHER-ASSERTIVE METHODS

What is authoritarian approach ?

In the broadest sense of the term, no method can be completely free of authoritarianism. As long as teachers and text books survive, authoritarianism will pervade. But here the term is used to denote methods which give more importance to the role of the teachers in educating, relegating the child and his interests to the background. The teacher dominates throughout the process It is an one man show, where the actual needs of the needed are neglected.

If mastery of the content alone is the objective of teaching science, these methods help much. They help the development of functional understandings and meanings of facts, concepts, laws, principles, theories, etc. In fact one major goal of teaching science is this. But, for the success of these methods, there are certain pre-conditions.[1]

1. Pupils must be able and willing to assimilate the information ;

2 The information must have intrinsic value (since the process of memorization is not in itself believed to confer benefits) ; and

3. The pupils must have some basis for evaluating what they have learned.

Unfortunately, these pre-conditions are rarely fulfilled at the secondary level. But at the higher levels, generally they are, and, therefore, there is better scope for the authoritarian approach at the college level.

The Lecture method, Demonstration method, Historical and Biographical approaches, Team teaching techniques ; etc., are the most popular authoritarian methods.

A. LECTURE METHOD (Telling method)

This is the most traditional of all teaching methods. Now it has become quite typical of college teaching. The origin of the method may be in the remote past, when there was no printing at all and manuscripts were very few just sufficient for the use of teachers alone. They were mastered by the teachers and their content was passed on to pupils by way of lectures

This is a highly teacher-centred method and in its purest form does not provide for any kind of response from pupils. Students just listen to what are beirg told by the teachers. There are no dcubts, no questions, no demonstrations.

The teachers have to prepare in advance for good lectures. They have to collect as many facts and information about the subject as possible, arrange them in a logical order, taking into consideration, the psychology of the child and present them in an impressive form.

Merits

1. For the transmission of knowledge, it is the best and easiest method. Factual information can be given in an effective and interesting manner.

2. The logical sequence of the subject can be kept. Because it is planned in advance and presented by a single person, there cannot be gaps in the development of the subjects.

3. This is a time saving method. Wastage of time is reduced to the minimum because there is no pupil activity, no time waste over projects or problems.

4. This is the best method for incidental correlation. The teacher can impart all that he knows from different subject areas, thus making the topic correlate with other subjects and with the environment of the child.

5. It gives the teacher and pupils much satisfaction. Students have a fancy in listening to impressive and fluent talks. If it is really interesting, they won't also forget it easily. They will have a feeling that they have studied much. Teachers get satisfied that they have done their job.

6. The method has high inspirational value. A good lecture may evoke ambitions in students, which would stand as an incentive for learning throughout the course.

Demerits

1. The method is not paedocentric. Children are only passive recipients of knowledge. Their interests, level of intelligence, previous experience, etc., are not given due weight.

2. Many of the major objectives of teaching science cannot be realised by this method very easily. The laboratory skill and the scientific mindedness cannot be developed by mere lectures.

3. The teacher may show a tendency for the superficial show of his scholarship. This may puzzle and confuse the students.

4. The domination of verbalism is another disadvantage. To make himself impressive, the teacher may use flourishing language and unnecessary adjectives, in the course of which, he is likely to forget the important facts and points to be covered.

5. The method is not democratic. It is authoritarian and there is indoctrination. It encourages the student to rely upon one authority, which hinders the development of the reasoning power and critical attitude, which are essential for the growth of scientific and democratic spirits.

6. It does not cater many areas of science. Science is not merely facts. The process of science, skills in observation, experimentation, etc., are neglected.

7. This gives no scope to test the previous knowledge of pupils and thus build a suitable superstructure. There is no incidental evaluation, and therefore the teacher is unaware whether the student has really learnt or not.

Conclusion :

Yet the method is not obsolete as it is considered often to be. That it still continues at the college level and that it has produced great scientists during a time when it was the only method of teaching, bears enough proof to the fact that it is a good method. It is admitted that in teaching science its scope is limited. Yet even here if properly done, on certain special occasions, it has some definite advantages. Saunders cites certain purposes of the lecture in teaching science.[2]

(*a*) To cover the syllabus quickly.

(*b*) To collect and summarize the results of the pupil's practical work.

(*c*) To open up a discussion as to where previous work may be leading and to obtain suggestions for further enquiry.

(*d*) To introduce a new topic, collecting together what information the class already possesses and outlining the sort of information that will be sought.

(*e*) To inform the class where relevant background materials may be found, where certain objects may be seen, certain operations watched ; in what periodicals appropriate articles or advertisements may be found or looked for ; in what shops certain pieces of apparatus or advertisement displays may be seen, and so on.

Even the higher objectives of teaching science can be developed by this method if the teachers are shrewd and resourceful. For example, the problem-solving skill. If instead of merely lecturing and presenting facts, the teacher reorients it and presents it by way of solving the problems, some of the skills and techniques involved in it may get transferred to students also.

B. Demonstration Method

The demonstration method seems to be the product of necessity. In the immediate past, when the number of students were very large and the availability of science teachers and scientific equipments were very limited, the demonstration

was the only method possible, other than the lecture method which was by that time recognised as insufficient for teaching science. In this method, the teacher instead of merely talking, also demonstrates experiments and asks incidental questions to students. The boys are active participants in a demonstration, they have to observe carefully and draw inferences from what they have observed. Students may also be given chances for simple demonstrations occasionally.

Richardson recognises seven functions for the demonstration.[3]

1. To solve a problem.

Examples :

To find the horsepower developed by a student in the class.

To learn, upon burning equal quantities of coal and wood, which produces more heat.

To determine whether commercial lotions for sunburn prevention are effective.

2. To explain, to make clear by analysis.

Examples :

Show the necessity of condensation nuclei for clouds.

Show the place of a catalyst through chemical reaction.

Show the effect of chest muscles on the flow of air into the lungs.

3. To verify, substantiate and review.

Examples:

Gather data on distance time relation of falling body.

Show that an acid-base reaction produces a salt.

Show that in the absence of sunlight, no starch is formed in a leaf.

4. To supply an application.

Examples :

Show the operation of the sound head in a motion picture projector.

Show the effect of a common ion by adding NaCl in soap making.

Show respiration of roots of wheat plants in a weak solution of congo red.

5. To evaluate student achievement—(for example, when a student interprets a new demonstration of a familiar principle),

Examples :

Determine the orifice velocity of water squirting horizontally from a hose by measuring distance it goes.

Reaction of Mg. Powder and Dry Ice.

Effect of varying light intensity on the growth of plants.

6. To create a problem.

Examples :

Predict the effect of a nearby source electrons on the size of water droplets in a jet.

Predict the relative velocities of molecules of HCl and NH_3 introduced into opposite ends of glass tube.

Predict the effect of iodine on metamorphosis of tadpoles.

7. To show methods and techniques.

Examples :

Winding a transformer coil.

Using a burette.

Typing blood.

8. To display objects and specimens.

Examples :

Cathode-ray tube—its parts and their functions.

Crystals of galena—their characteristics.

Leaves—the parts and their functions.

The demonstration method is highly desirable.

1. When the experiment involves danger.
2. When the apparatus is costly and unsuitable for young pupils to handle.
3. When the apparatus is very sensitive that it may be damaged by rough handling.
4. When so many related experiments are to be performed during a period and
5. When the objective is a quick revision, and above all,
6. When the teacher is fully convinced that the experiment is so complicated that his pupils may fail to perform it.

For successful demonstration, it is better if the teachers bear in mind the following points.

1. Demonstrations should be rehearsed in advance : However experienced and skilful a teacher be, he should try out the experiments in advance, before they are actually performed in the classroom. Sufficient care should be given even on silly matters. It is better if a spare set of apparatus is reserved. A failure of the demonstration disappoints the pupils and affects adversely the impression about the teacher. "No other form of teaching gives a pupil such a feeling of disappointment as a badly prepared science lesson where nothing 'works'."[4]

2. The purpose of the demonstration should be made clear to the pupils : The awareness of the objectives of the demonstration makes it more meaningful for the pupils. Otherwise, they may see things ; but may not find meanings in them. If objectives are not revealed in advance, they can be revealed during the course of the demonstration step by step.

3. The results of the demonstration should not be told in advance. They should observe things clearly, exercise their reasoning and arrive at their own conclusions.

4. The demonstration should be visible to the whole class : Attention should be taken about the position of the students in the class, the place of demonstration, the size of the apparatus and also lighting of the classroom. Saunders suggests even the erection of a mirror above the demonstration table so that everything will be visible to all students.[5]

5. The experiments should be well spaced throughout the lesson. It should be a part of the teaching process and distributed throughout the lesson. There should not be any separate time allotted for demonstration.

6. Only the simplest form of apparatus should be used : Using a complicated apparatus to demonstrate a simple experiment tends to make it vague. It is better to use improvised apparatus.

7. A demonstration should be utilised to the maximum extent for the realisation of objectives : Demonstrations should

not become ends by themselves. The teacher should exploit it by all means and try to develop scientific mindedness through the realisation of the advanced obectives of teaching science.

8. There should be variety in demonstrations: A demonstration should not be repeated too many times. New experiments, other than those prescribed in the text books should be preferred. If there are many experiments possible on a single aspect, then all of them need not be demonstrated in the class. If they are simple let the student try them in the home as assignment.

9. The teacher should be aware of time, season, and background of demonstration: For example, experiments on magnets should not be performed in the background of or near magnetic substances. Demonstrations on static electricity may be failures on rainy days. Wet weather is ideal for deliquescence and dry for efflorescence. Experiments which involve changes in colours should not be performed against colour backgrounds.

10. The blackboard should be properly used during the demonstration : Details of the experiments, recordings, outcomes of the experiments, etc., should be written on the blackboard.

11. Discipline of the class should be maintained: If the students really get involved in the demonstration, then discipline is no problem.

12. There should be pupil participation in the demonstration: Assistance of the students may be sought occasionally. Simple jobs like reading scales, fitting an apparatus, describing and helping the teacher in many other activities give the students much psychological satisfaction.

13. Several demonstrations should not be displayed at the same time : Each demonstration should be shown at the right time only and should be removed away after use. A wealth of apparatus may impress the students, but it may also equally confuse them and distract their attention.

14. The demonstration should not be too long: An experiment which lasts for a long time won't sustain the interest of

students. It should be covered within a period. If simple experiments are time consuming, they can be left to the students to perform in their homes. (Example: Developing a copper sulphate salt in copper sulphate solution).

15. Demonstrations should be problem centred: If they are not problem centred, demonstrations would become mere laboratory exercises.

16. An element of suspense is good : It interests the students, especially of the lower standards.

Merits

The main advantages of the demonstration method are the following :

1. It is the least expensive method of utilising laboratory activities: As the teacher alone conducts the experiments only one set of each apparatus is necessary. Because of this, this method is highly suitable for Indian schools which cannot command enough money to buy materials to suit individual requirements.

2. The method is time saving: Though when compared to the lecture method, it consumes more time, in contrast to many other modern methods like Experimental method, Problem and Project methods, etc. it saves much time.

3. The method provides activities for the students : Though not purely paedocentric, it provides students with a lot of activities. They have to observe carefully, take notes, draw figures, answer questions, etc. Thus they are kept fully engaged.

4. The method is better for the average and less than average students of the class. They get a guideline to follow. If all of them have to do experiments by themselves, many of them may not do it successfully.

5. There is uniformity in teaching: Though it cannot be said to be an advantage when ideal conditions are available, the teacher develops a psychological satisfaction that he had done alike to all students.

6. The subject matter is taught in a well arranged form : Since the teacher is supposed to be more efficient than all students, his performance before the students will always yield

better results. He knows better than the students, the objective of the course and therefore the learning process becomes well arranged and integrated. Many modern methods whatever be their other merits, provide only disintegrated pieces of information which means no sequential meaning at all to the students.

7. The method can develop some aspects of scientific mindedness: When the teacher does the experiments, he explains and interprets it with the co-operation of the students. If properly done, this can develop scientific mindedness in students. There are experimental evidences to prove that it is in no way inferior to the Individual Laboratory Method.[6]

Demerits

1. The method is not paedocentric : Pupils are not made active participants. The conduction of the experiments becomes the sole responsibility of the teacher, that the students show no interest at all in it.

2. It does not cater for individual differences : All students do not learn alike. Though the teacher gets satisfaction that he has taught all alike, all of them won't learn in the same way. The rates of comprehension and understanding vary and the students get no freedom to proceed according to their abilities.

3. The laboratory skills are not developed in children : As they are not conducting the experiments and handling the apparatus, skills in setting up apparatus, observation, manipulation, etc., are not developed in children.

4. All senses are not catered for. Only by sight and sound much scientific information cannot be acquired precisely. "Odors require close-up observation. Texture is best determined by touch. Forces are more significant when muscular action is involved."[7]

5. Indiscipline often mounts in the classroom : As the teacher gets engaged in the experiments, he has to concentrate upon it solely. Students, eager to observe what is going on, may create indiscipline in the classroom.

6.. During the time of discussions and question answers, intelligent students may dominate, to the disadvantage of others.

But these alleged demerits cannot stand in front of a good teacher in accepting this method. Though not as a sole method, he can use it with many paedocentric methods to get best results.

C. The Historical Method

This is more a way of arranging and presenting syllabus than a teaching method in the strict sense of the term. But in the broader sense it can be a method also and when it is a method of teaching, it depends more on the teacher than on the pupils and therefore classified under Teacher-Assertive methods.

Overemphasis on the logical development of science subjects is likely to discard the historical aspect of it which differs very markedly from the former. Science has followed devious routes and curved lines. Sometimes false theories are held for a long time and much time has been wasted over that. Our students also should get an idea about this, when they study science. This alone will reveal the romance of science to them. Therefore the method insists on presenting science in the order of its historical development. For example, in teaching the nature of heat—the caloric theory, Rumford's experiments, Joule's experiments, etc., should be the order of development.

Anyhow as is evident, this method is time consuming. Time is unnecessarily wasted over false concepts and exploded theories. Again many of the objectives of teaching science subjects cannot be realised properly. For example, skills in observation, experimentation and, in general, scientific mindedness.

Though cannot be treated as the only method, a knowledge of the history of science is highly essential for the science teacher. It enables him to introduce some theoretical concepts in a better way. The method also reveals to the students the growth of sciences—the natural continuity of discoveries and inventions. It is also psychological because the pupils' knowledge, ideas and way of approach are similar to those of the original

discoverer. The history of science is the history of human race. This attitude can be properly developed by following the historical method.

D. Biographical Method

This also is more an approach in syllabus construction than a teaching method. When it becomes a method, it denotes more a change in the attitude of the teacher than a specific technique of teaching.

Many educationists are in favour of the Biographical treatment of science subjects. The Biographical method deviates only very slightly from the historical methods. The latter follows the course of development of science strictly. It only retraces the historical route. But the Biographical method is centred around individual scientists. "......the biographical method follows the original discoverer's success and failures, his hopes and disappointments—all that constitutes the 'romance' of science."[8]

The Biographical method emphasises the human interest for adventurism. It is an expression of the human spirit and is against a pure materialistic presentation of the subject. At present the school science is very materialistic and is lacking this human element. "The romance of modern scientific discovery and invention is a sealed book to them (pupils) and the humanizing influence of the subject has been kept entirely from them."[9] The Biographical method has a romance of its own. To get the best results, the historical method and the biographical method can be combined. The biographies of eminent scientists like Darwin, Pasteur, Genner, Newton, Faraday, etc., are rich with scientific theories and discoveries. As has been stated, the history of science is nothing but the biographies of some scientists. Students can take a good lesson from their dedications to the cause of humanity, their hardworking nature, their resourcefulness and their difficulties and pitfalls.

This method also is time consuming. In its worst form, time is wasted over unnecessary details in the life histories of csientists. It is also to be doubted, whether the student is

really interested in the biographies of scientists. "When a boy first comes to the natural science class, he is more interested in change of colour in starch test, than in the phenomenon itself. He does not like to be bothered with the biography of Lavoisier, when he is burning bits of magnesium and observes and enjoys the change of colour or with the biography of Pasteur, when he is listening to an interesting talk on rabies and treatment."[10]

But the teacher can do better, if he is well versed in the biographies of scientists. It enables him to understand what scientific life is. The narration of anecdotes from the life histories of scientists may inspire the students very much. As an occasional method, therefore, this has much value.

E. Team-Teaching

Team-teaching is a recent development among the techniques of instruction. It is not a method by itself, but only a technique of teaching. It is classified along with the authoritarian approach, for, as it is practised now, teachers dominate the activities.

Team-teaching is a co-operative endeavour, where more than one teacher co-operatively develop a programme of instruction and share in teaching, evaluation, etc. "The reaction of the teachers and pupils to the program are very favourable. The teachers believe that instruction has been improved tenfold by using the technique. The work load of teachers is decreased so that more time can be devoted to preparation of lectures, materials, and laboratory, permitting better instruction. The teachers of the team get a chance to exchange ideas where this was not possible in a conventional teaching situation."[11]

The method has one unique advantage of putting together different talents of various teachers. The characteristics of this technique are listed by Lacey as follows[12] :

1. It encompasses all aspects of the teaching-learning experience.

2. Two or more teachers co-operatively plan for, instruct

and evaluate one or more class groups in a specific, instructional area and given length of time.

3. The special competencies of each teacher are drawn upon and utilised at the appropriate time and place.

4. There are more flexible schedules than are found in conventional school situations.

5. Space and instructional media can be utilised more appropriately for the purposes and content of the instruction.

The assignment of roles to different teachers should be so done as to get the best results. Some teachers can plan well, some can guide well in the laboratory, some can teach well. The arrangement should be so done so that each gets chance to the maximum utilisation of his or her talents.

At present, even where this teaching is practised, it is based on lecture method and discussion method. This is not so good. If the discovery methods are also properly integrated with it, the technique may yield better results.

Summary

The authoritarian methods lay more stress upon the role of the teacher in teaching. The Lecture method, Demonstration method, Historical method, Biographical method, Team-teaching, etc., are Teacher-assertive methods. All these have their own merits and demerits. Any one of them cannot be followed as a sole method of teaching science. But if occasionally combined with Discovery methods, may yield better results.

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CHAPTER XII

DISCOVERY APPROACH AND CHILD-ASSERTIVE METHODS

The discovery approach in teaching science was the result of psychologising education. There are a variety of methods, which have accepted teaching through discovery or enquiry. Many of the drawbacks of the authoritarian approach are rectified here. It is an attempt at individualising instruction making it child-centred. Again enquiry approach in general enables the development of capacities for interpretation for "......the knowledge won through enquiry is not knowledge merely of facts, but of the facts interpreted."[1] The training in interpretation of facts results in critical,creative and rationalistic thinking. "The major contribution of the discovery approach, when properly carried out, is the opportunity provided for independent thinking. Pupils are challenged with suitable problems, they then plan and carry out their own attacks on these problems, they collect and organise their own data, and they draw their own conclusions. The teacher helps and encourages but does not dictate."[2]

But the discovery approach is generally more time consuming than the authoritarian approach. Not only that, many of the topics are not vulnerable for the discovery approach. But for developing scientific mindedness the discovery approach should always be preferred.

The Experimental method, the Problem method, Project method, Heuristic method, Dalton Plan, Winnetka Plan, Developmental method, Assignment method, Unit method, Programmed learning etc. are some of the most popular child assertive methods.

A. The Experimental Method

The experimental method insists on students conducting

experiments and arriving at their own inferences, under the guidance of the teacher. When applied to science, experiment and laboratory work are more or less similar, but not same. "There may be some experimentation done outside the laboratory, and some laboratory activities cannot be called experiments. But in practice most of the experiments done by the pupils are part of their laboratory work and most of their laboratory work involves experimentation."[3] The laboratory is often regarded as the heart of science. It avails itself for a number of activities from different areas of science. "While the laboratory may have walls, it has really no bounds, it may draw upon all the sources of the universe."[4] The laboratory is more a method and an approach than a mere place of activities.

In the experimental method, each pupil is provided with separate apparatus to perform experiments, at his own desk in the laboratory or outside. They may also be provided with manuals containing detailed instructions of procedure regarding the experiments to be performed. The teacher only offers guidance whenever necessary.

Experimental method is based on the principle of discovery. The students should get ample chance for the display of their talents by way of planning procedures, choosing suitable method, arriving at conclusions and also reporting findings. The teacher never intervenes directly, but only moves about giving encouragement, clarifying procedures, removing misunderstandings and stimulating to undertake more work.

Blough has summarised certain general principles for the success of the experimental method.[5]

1. Experiments should be conducted in such a way as to make pupils think.

2. Children should be conscious of the purpose for performing an experiment.

3. Careful planning is essential to successful experimenting.

4. In so far as possible, children themselves should perform the experiments, working as individuals or as groups.

5. Many times children can suggest experiments to answer their own questions.

6. Experiments should be performed carefully and exactly.

7. Pupils should learn the value of controlled experimentation.

8. Simple apparatus is more appropriate for use in experiments in the elementary schools (and junior high schools) than complicated materials.

9. Pupil should exercise great caution in drawing conclusions from experiments.

10. As many applications to everyday life situations and problems as possible should be made from an experiment.

Experiments vary widely. There are simple and easy experiments as well as complex and sophisticated experiments. Experiments should not be overformalised. They should be flexible and adaptable.

Experiments can be performed with five objectives in view.[6]

1. An experiment to illustrate a principle.
2. An experiment to find a numerical result.
3. An experiment to produce something.
4. An experiment copying an experiment carried out by a famous scientist.
5. Original work.

In the case of experiments for finding out numerical results, children may be given chance to use good apparatus. This develops in them the importance of scientific accuracy. The sources of errors, if any, should also be pointed out. In case of experiments meant to produce something like the preparation of chemicals, etc., the work should be within the capacity of children. Detailed instructions regarding the procedure to be followed must also be furnished. If the teacher himself conducts early demonstrations, it may yield better results.

The chief aid in the experimental method is the laboratory itself. Richardson lists the major contributions of the laboratory to the teaching of science as follows.[7]

1. The science laboratory is a source of problems for students to solve or attempt to solve.

2. The science laboratory provides for the solution of problems the students have encountered in the laboratory, the classroom or elsewhere.

3. The science laboratory promotes the students' understanding of the scientists' role in our society.

4. The science laboratory provides illustrations of phenomena, of principles and of their application ; it provides the means to verify facts, laws and generalisations.

5. The science laboratory contributes to the students' knowledge and understanding of facts, principles, concepts and generalisations of science.

6. The science laboratory contributes to the development of skills, habits and attitudes.

To get best results from the laboratory, the activities should be well planned. It should be more a place of experiments than mere exercises. The teachers and students should plan thoroughly before conducting experiments. When there are dangers involved in an experiment, special instructions should be given for it. Though there is a manual for experiments, neither the teacher, nor the students should follow it slavishly. There should be sufficient room for the display of ingenuity.

Merits

1. The method implies the principle of learning by doing. Knowledge gained through this method, is gained in an interesting way and therefore is retained for a prolonged period of time.

2. Being a child-assertive method it provides for active participation of students in the learning process.

3. The pupils get opportunities for the handling of materials. This enables them to develop the manipulative and laboratory skill.

4. The child becomes the unit of instruction. Each student has to conduct experiments by his own. They can proceed at their own capacities. Brighter children can perform more experiments, whereas the dull and average can proceed at their own pace.

5. The students get training in following directions. He has to follow the manual and perform the experiments. This

gives him sufficient training in following directions from an authoritative source.

6. The scientific mindedness is gradually developed. The students perform the experiments, record the observations and arrive at their own conclusions. This develops in them qualities of independant and critical thinking and scientific mindedness.

Demerits

1. The method is very expensive, because many sets of apparatus become necessary. It implies a lot of investment. There is recurring expenditure also by way of consumption of chemicals and other articles.

2. A lot of time is wasted. Students are unskilled workers. The skills of the laboratory are strange to them. Naturally, they ponder over equipments thus making it difficult to cover the syllabus within the time specified.

3. All portions of the syllabus are not vulnerable to this method. There are some portions which involve no experiments at all and some are so complicated that it cannot be performed by students.

4 If the teacher is indolent, the experimental activities of the students remain unguided and unsupervised. This results in the pupils developing a dislike for the subject.

5. There is no guarantee that the students may solve problems or think scientifically. Generally, the dull and average students, copy down the results of the more brilliant ones.

6. Though the method develops laboratory techniques and experimental skills, for the majority of students, they are of no use at all in their future.

7. The method is not so suitable at the lower stages.

8. The method being highly individualistic, does not cater for the social objectives of teaching science.

9. A lot of time of the teacher is wasted in planning and supervising activities, checking up apparatus etc.

In the Indian conditions, the method has not so much scope because of the heavy financial implications. And even

with this, it has proved to be only as good as the demonstration method which involves only about 7% of its expenditure. But the spirit of this method can be followed especially in Biology classes, in the observation of plants and flowers etc., and in simple, inexpensive experiments on photosynthesis, osmosis and the like.

B. The Heuristic Method

The term 'heuristic' has its origin from the Greek word 'Heurisko' which means to find out. As the very name indicates, the method lays stress upon children gaining knowledge and skills by way of their own discovery.

Though the method has its psychological basis on the writings of Pestalozzi, Locke, Rousseau etc., it was given its final form by Prof. H.E. Armstrong, the great professor of chemistry. He argued that the spirit of science is original investigation and discovery. Therefore his method also puts the pupils in the very same position of the original investigator, no help being extended by any source. Armstrong himself describes the heuristic method as follows : "The heuristic method of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer—methods which involve their "finding out" instead of being merely told about things."[8]

Science lessons should be in the form of enquiry. Students have to solve so many problems graded according to their I.Q. This alone can properly develop the power of reasoning and imagination, which in their turn lead to devising and fitting up of apparatus, conducting experiments etc. The pupils independently discover facts, hypotheses and laws experimentally. The method calls for very accurate measurements and very keen observation. "Essentially, therefore, the heuristic method is intended to provide a training in method. Knowledge is a secondary consideration altogether. The method is formative, rather than informational. Such training if properly carried out, does cultivate painstaking and observant habits and encourages intelligent and independent reasoning. It does bring home to boys clear notions of the nature of

experimental evidence, and boys do learn, that answers to questions can often be obtained from experiments they can work for themselves".[9]

Merits

1. The child gets importance in this method. The method is paedocentric and the child is the unit of instruction.

2. The method gives importance to science as a process. The interest of the students is awakened and sustained in scientific method. They get training in arriving at valid conclusions.

3. The method provides enough training in manipulative skill and laboratory techniques.

4. As the students invent things for themselves, they develop a sense of self-confidence.

5. The method is based on the principle of learning by doing. Because knowledge is acquired by first hand experience, it is retained for a longer period of time.

6. To some extent, the method caters for individual differences. Children of different intelligence level can proceed at their own pace.

7. As the students have to work as original discoverers, they get an idea of the romance of modern scientific discoveries and inventions.

Demerits

1. The method lays too much stress upon science as a process, neglecting science as a product. But science is scientific knowledge also and any programme which advocates one at the expense of the other is lopsided.

2. Many inspiring, historical experiments are put into the background.

3. Since the children are extended no help at all, they are likely to be frustrated and thus develop a dislike for the subject.

4. Many of the laws are too difficult to be discovered by students. In fact, they have been discovered by many years of

concentrated attack of scientists and it will be too much to ask children to discover them for themselves. "A beginner in science may discover a test tube hidden in a drawer, but rarely a principle lurking in a group of facts."[10]

5. Some experiments which require the skills of a trained teacher and also some types of apparatus which can only be used in demonstration are to be neglected.

6. Much time is wasted over rediscovering things already discovered.

7. The method is lacking in vitality. It has no scope for the proper role of the teacher, by way of appliances and specimens brought by him, questions asked by him, guidance offered by him and above all his enthusiasm and personality. If the teacher renders all these, the method ceases to be purely heuristic.

8. Many topics connot be treated according to the heuristic methods, because they involve no discovery at all.

9. All pupils cannot be considered as potential scientists. Many of them may be lacking the innate mental qualities which the scientists possess.

10. As the children are not aware of the objectives of the whole procedure, the whole activity becomes meaningless for them.

11. The heuristic method is quite unpracticable on a large scale. This is highly expensive and requires exceptionally good teachers who will not spoil the spirit of the method when they follow it.

12. The method may leave gaps on the knowledge gained. As there is no provision for discussions and summing up, it lacks co-ordination.

13. The method may bring administrative problems. It is difficult to fit it with the ordinary classroom teaching.

14. As there is no group work and co-operative activities, the method becomes highly individualistic and thus neglects the social aspects of education.

Though unpracticable in the Indian conditions as the sole method of teaching science to high school pupils, it is highly essential that the spirit of 'heurism' remains throughout any science course. The pupils should be given liberty to choose problems in which they are interested. The objectives of the whole thing must be revealed to the students before hand, the results should never be foretold. Only as much guidance as is necessary for the students alone be provided by the teacher. Whenever possible, the students must be let to discover things for themselves. Pure lecture method, as a rule, should be avoided. Instead training in observation, experimentation and scientific thinking should be provided. When demonstrations are conducted, it should be along heuristic lines.

C. The Problem Method

The problem method can be said to be an off-shoot of the heuristic method. But unlike in the case of the heuristic method, here the teacher can step in and offer guidance and directions whenever necessary. The method also is against information hunters and bookworms and considers science more as a process. It is based on the scientific method of thinking and the broad outlines of scientific thinking are the steps followed in problem solving. According to Dewey the various steps involved are :

1. Sensing a problem.
2. Definition of the problem.
3. Collection of data relevant to the problem.
4. Formation of hypotheses and
5. Acceptance or rejection of the hypotheses.

1. *Sensing a problem* : The whole method is built around problems spontaneously evolving from classroom discussions generally under the guidance of the teacher. But when the students fail to come forward with a suitable problem, the teacher has full liberty to lead them to the problem under the same topic. When selecting the problem, the following points may be borne in mind by the teacher.

1. It should be neither too difficult nor too easy.

2. It is better if it is related to the environment.

3. The problems should be novel to the students. At the same time, they should have sufficient previous knowledge and basic information needed to solve the problem.

4. The problems should be within the intelligence level of the students. They should be able to solve at least part of the problem.

5. The problems should have variety. They should not be too bookish, but should be of the thought provoking type.

6. The problems should also provide for setting up hypotheses and their solutions.

7. The problems should have coherence and sequence. They should be concrete especially at the lower stages.

2. *Definition of the problem* : Before embarking at the solution of the problem, the teacher should consider, whether a problem is set out in the best possible way. If the problem is a complicated one with different faces, it must be split up into simpler parts. The wording of it should be unambiguous and unequivocal.

3. *Collection of data relevant to the problem* : After understanding the problem clearly, the next step is to collect the information which will lead to a solution. There are various sources of getting information. This may be from the library by reference to books or magazines, or from the laboratory through deliberately planned experiments or from persons possessing the necessary knowledge by conducting interviews, or by observations during field trips and excursions.

4. *Formation of hypotheses* : After organising, classifying and arranging the information collected, the students by critical and creative thinking propose possible answers for the problem. In doing so all possibilities are taken into consideration and even those hypotheses which would seem too silly are considered.

5. *Acceptance or rejection of hypotheses* : Each hypothesis is then subjected to further trials and tests are designed to prove their validity. If the hypothesis is true, it will hold on varieties of conditions other than and similar to the one

which leads to its propounding. Each hypothesis is tested like this and the most suitable ones alone are selected. If some hypotheses show exceptions, they are modified to include the exceptions also. From these valid hypotheses further predictions are made.

It may be noted that these are not clear-cut steps which any one engaged in problem-solving should strictly follow. Often mind takes its own course. But at least in their vague form, these steps appear in the thought process.

Example[11]. Rusting—Why does iron sheets, used for roofs, rust and have to be replaced ?

(*a*) Sensing the problem. Here is a practical problem. that affects the owners of houses and other buildings. It is serious, because a great deal of money is spent, all over the world, on roofing materials. The money needed for frequent replacements could often be used for other important purposes.

Considerable damage may be done when roofs leak ; things inside the buildings may be ruined by rain, and the walls may remain wet for long periods and finally break down. Rusty iron roofs give an unsightly appearance to a town or village and visitors get a poor impression of the inhabitants. Interest in the problem may thus be aroused form either the practical or the aesthetic point of view, preferably from both.

(*b*) Analysis of the problem. The next stage is to sort out the factors which may be involved, to break down the problem into smaller parts, which, when solved, may provide an answer to the whole. The kinds of questions which may now be asked are :

(*i*) Does constant wet weather or constant day weather affect the rate of rusting ?

(*ii*) Do iron roofs rust faster in hot than in cold places ?

(*iii*) Are there roofs made of other metals, and do these rust and need replacing ?

(*iv*) How does the rust differ from the original iron sheet ?

(*v*) Iron roofs are sometimes painted. Does this serve any useful purpose or is it merely to improve the appearance ?

(*vi*) Where does rusting first begin on an iron sheet ?

(*c*) Collecting the evidence. The questions which have arisen must now be examined and the answers sought by systematic inquiry. There is no limit to the range over which it is possible to search for evidence. Experiences in the laboratory, the rest of the school, the school compound, the home, the village or more distant places, may all yield useful suggestions. Pupils who have read widely, or have developed good habits of observation, have an immense advantage over their fellows in the value of the contribution they can make to this stage of the lesson.

The laboratory is a place where, on a small scale and under controlled conditions, happenings in the world outside the school may be repeated. A full-size iron roofing sheet is too large and expensive to bring into a laboratory, but a smaller piece, either cut from a larger sheet or found discarded on some building site, will serve the purpose.

A new piece of iron sheet, examined closely, will be seen to have a surface patterned with bright streaks, apparently crystals. Scraping with a sharp instrument seems to expose a different metal surface underneath. The partly scraped specimen should be handed around the class for examination, because here may lie an important clue to the understanding of the whole problem.

Taking the questions raised, one at time, but not necessarily in the order in which they were asked, action might be as follows :

(*v*) A pupil is selected to ask a local builder, or an engineer, whose business it is to put up or maintain roofs of this type, whether in his opinion, painting lengthens the life of iron sheets. This is a task to be carried out during out-of-school hours, not in class time.

Perhaps a member of the class knows of two roofs, erected at about the same time, one painted and the other not, and may be asked to find out whether there is any evidence that one lasts longer than the other. (*i*) Is any evidence available ? Does any pupil know two areas of different climate well enough to be able to venture a useful option ? If not, does any pupil

know of an iron sheet upon which water constantly drips, for example from an overflow pipe, and is there any reason to think that this rusts faster than might be expected ? Where is this example to be found ? Others should be able to examine it. If there seems to be no convenient example, which can help to answer the question, is it possible to arrange for some samples of sheet iron to be kept wet, and others dry so that any difference in rate of rusting may be noted ?

This may lead to suggestions for an experiment : Small pieces of iron sheet are placed in three test-tubes of water. (1) In the ordinary state, (2) after scraping with a sharp knife, (3) after painting.

If pupils have already learnt that when water boils, the dissolved air is driven out, this is the time to revise, and obtain the suggestion that three similar types may be put into test-tubes, the water boiled, and stoppers at once employed to exclude air. The six test-tubes are then prepared and labelled.

(*iii*) Does anyone in the class know of roofs made of sheet of metal other than iron ? Aluminium sheet is being increasingly used, and lead sheet has been used for the purpose for at least 2000 years. Do these rust as fast as iron, or more slowly, or not at all ? Can we find out ? Samples of metals are required, so that a piece of aluminium and a piece of lead may be put in two test tubes of ordinary water, and similar pieces of each in test-tubes of boiled water. The four samples are labelled and placed with the others.

Are there any other metals which might be used for roofing ? Perhaps—zinc, tin, or tin sheet (the material of which the 'tins' (cans) of preserved foods are made).

Evidently a few more specimens must be added to those already set out. So pieces of zinc foil, tinfoil, and tin cut from an empty food container are immersed in ordinary water, and boiled water, as in the previous cases.

(*vi*) the results of the experiments should supply the answer to this question.

(*ii*) Pupils cannot find out directly whether iron roofs rust faster in hot than in cold countries, and it will probably be

impossible to perform suitable laboratory experiments. This class may have to wait for a lesson about the effect of temperature on the speed of reactions, or may simply have to accept the fact that chemical reactions are slower when the temperature is lower.

(*iv*) Suggestions for an experiment to find the answer to this question may have to wait until the results of the others are available. If, however, from his reading a pupil is able to suggest that the difference is brought about by iron taking oxygen from the air, the usual experiment may be set up. A little water is shaken up in a long glass tube closed at one end, and poured away. Iron filings are then dusted into the tube so that they stick to the wet sides. The tube is then inverted over a beaker of water and left to stand.

(*d*) Interpreting the evidence.

(*v*) The report from the builder or civil engineer will show that painted iron roofs last longer than unpainted ones. It may also point out that roofing sheets should not be scratched, and that the number of nail holes should be kept to the minimum.

(*i*) Evidence provided by the specimens in the test-tubes may be summarized thus :—

Specimen	*Effect of ordinary water*	*Effect of boiled water*
Scraped iron sheet	rusts	does not rust
Plain iron sheet	rusts at edges	does not rust
Painted iron sheet	does not rust	does not rust
Aluminium sheet	does not rust	does not rust
Lead sheet	does not rust	does not rust
Zinc foil	does not rust	does not rust
Tin foil	does not rust	does not rust
'Tin' sheet from food can	rusts at edges	does not rust

(*vi*) Rusting begins at the cut edges.

(*iv*) The iron filings rust, water rises part way up the tube and then stops at a certain level.

(*e*) Conclusions. The results of (*i*) and (*iii*) in respect of metals immersed in boiled water, show that it is the presence of air that promotes rusting. The results of (*iv*) suggest that there is a part of air, and only a part that is concerned with rusting. The conclusion is that if air can be kept away from iron, for example by a protecting coat of some non-rusting metal (such as zinc, tin, or lead), the iron is not likely to rust. If the iron roofing sheet is scraped, or where the edge of the iron is exposed by cutting, then the iron is unprotected and rust. Paint is also useful because it forms an airproof covering. Scratches and nail-holes should be avoided as far as possible, because they damage the protecting surface and so lead to rusting. Summarizing the conclusions arrived at so far :—

The iron used for roofing is usually covered by a protective layer of rustless material. This layer appears to consist of another metal.

Painted iron does not rust.

Rusting takes place readily in the presence of water and air.

Rusting uses up a part of the air.

To prevent iron roofing from rusting it is covered with another material to keep the air away.

In the course of trying to solve a problem, it is often found that other questions arise and these must be solved in their turn before a final answer is obtained. The routine of analysing the problem, working out appropriate experiments and collecting and interpreting the evidence has to be repeated for each question.

In the example of the iron roofing sheets, a further question arises. 'What is the layer of metal that covers and protects the iron ?'

Apart from an analysis which is beyond the ability of a general science class to understand at this stage, the possible answer is that it might be zinc, tin, lead or some other non-rusting metal. The teacher may then tell the class that the metal is, in fact, zinc and that the roofing sheets are usually called 'galvanised iron'. He may describe how they are made by dipping them, when perfectly clean, into a bath of molten

zinc. He may also inform the class that the 'tin' (can) in which food is preserved, and in which so many other articles are packed, is, in fact, iron sheet covered with a layer of the metal tin.

Thus questions, designed experiment, evidence and information are fused together to provide an answer to the original problem.

(*f*) Practical applications. The conclusions that have been drawn about the rusting of iron have many practical applications. The evidence suggests that roofing sheets, should be treated carefully if they are to last, that paint over the layer of zinc gives additional protection to the surface, that sheets of matals other than iron are likely to last longer, and that there is considerable future for the use of aluminium, which does not rust, requires no metal covering or painting, and will last for many years.

(*g*) Subjects for further study. Branching off from the iron roofing sheets problem there are now other problems that may be pursued further. The question (*iv*), 'How does the rust differ from the original iron sheet ?' has not finally been disposed of. When it is placed by the side of the question 'what happens when things burn ?' the similarity of the fraction of air used up in each case provides one clue to the answer. There follows a study of oxygen, and the preparation and composition of oxides, with basic and acidic oxides, and then a long series of problems comes into view.

This kind of treatment of a problem should be a regular feature of science lessons, so that pupils come to regard it as normal procedure and to adopt it as a habit.

Merits

1. The method is centred around problems and this gives purpose and direction for the students to work. It is paedocentric, child becomes active participant in the learning process. Since the method has accepted the spirit of the scientific method, it develops in them scientific way of thinking.

2. As the problems are related to the pupils' environments,

while they solve them, they develop a scientific understanding about the nature.

3. The method is better for the above average group. Some of the problems may challenge the brilliant students of the class and stimulate them for further hard work.

4. If conducted along group lines, the social values can be developed in children.

Demerits

1. The method is time consuming. It takes generally long periods for children to solve by their own, even comparatively simpler problems.

2. All portions of the syllabus cannot be treated in the problem approach.

3. The method is not so good at the lower stages, when the students are likely to be less capable for critical thinking.

4. To find out new problems, becomes a tedious task for the teacher. However resourceful the teacher be, the stock of problems is likely to be exhausted within a few years. If problems already solved are provided, the method becomes stereotyped and instead of problem solving, it becomes mere problem doing.

5. Lack of well prepared reference material will be keenly felt especially in Indian conditions. The syllabus and text-books are not prepared to suit the problem approach. The community also won't suffer for a long time, the mass of students troubling them always for data. Sometimes enlightened members to whom references are made, may provide the answer to the problem, which would destroy the very objective of the method. (For ex : An engineer to whom the matter rusting is referred may provide very well the reasons for rusting. In this case how can the students 'solve the problem' further ?)

The above demerits prevent it from being accepted as the sole method of teaching science in India. But the spirit of the method can be integrated—and is integrated—with the Develop-

mental Method and the Unit Plan that are now being generally followed in India.

D. The Project Method

The project method is based on the philosophy of pragmatism and the principle of 'learning by doing'. The method has had its origin around the year 1908 in an agricultural school of Massachusetts and was first introduced by Mr. Stevenson in the year 1908. Stevenson himself defines the project as "a problematic act carried to completion in its natural setting."[12] Dr. Kilpatrick defines the project "as a whole hearted purposeful activity proceeding in a social environment."[13]

The problem method solves the problems at the mental plane whereas the project method solves them, both at the mental plane and practical plane. It takes pupils out of the monotonous classroom atmosphere and gives them a chance to mingle into the realities of life. Knowledge is gained by doing things and as a result of some need that arises. The method is highly psychological and is best suited to the adolescents who have a strong thirst for doing things.

The contributions of this method are summarised by Thurber and Collette as follows :[14]

1. Stimulating an interest in science.
2. Satisfying scientific curiosity.
3. Developing problem solving techniques.
4. Encouraging independent thinking.
5. Giving practice in critical thinking.
6. Developing an appreciation for the work of scientists.
7. Making scientific principles more meaningful.
8. Helping develop each individual to the utmost.
9. Increasing self-confidence.
10. Grouping experience with tools and techniques.
11. Filling leisure time to good advantage.

When students undertake the project independently, they are called 'individual projects'. But when one group or the class as a whole deals with the problem it becomes 'Group Project'.

There are a variety of projects possible at the school level. They include Collection projects, Identification projects, Construction projects, Observational projects, Dissection projects, Survey projects, Excursion projects, Exhibiton projects, Dramatisation projects, etc. Whenever there is some activity on the part of the students, in the broadest sense of the term, it becomes a project.

Every project work involves four phases.

1. Purposing
2. Planning
3. Execution
4. Reporting

1. *Purposing* : This is the first step in the undertaking of a project. Here the problem is selected and understood properly. It may emerge as a result of a discussion in the classroom. If the students fail to select a suitable project, the teacher can very well lead them to the relevant projects by way of informal talks.

The following are the criteria of a good project :[15]

1. A project should have definite educational value.
2. The educational significance should be related to the needs of the pupils and should be quite apparent.
3. It should be adapted to children's needs and suited to their age and intellectual and social backgrounds, and to the availability of materials.
4. There should be some proportion of the values derived from a project and the time spent on it.
5. It should be capable of completion within the time limit set for the course.

The projects need not be always new. Even if it is a traditional one, because a new student is doing it, he will do it in his own way. "Even though a student may appear to be copying the design of a devise, invariably he will inject a new idea."[16]

The project is to be so represented as to be a real challenge for the students.

2. *Planning*. This is a stage which involves much activity on the part of the teacher. "Planning and carrying out 'units' and 'projects' involves much more work on the part of the teacher than the customary routine of uninspired science lessons. Natural lassitude and indolence can soon overcome original enthusiasm. The teacher should be alert and well informed. He should be constantly accumulating a collection of teaching material in the form of papers, illustrations, articles, reports and exhibits. He must be able to direct his pupils to the information they seek. He must co-operate with the other teachers in the school, so that all the work of the class may be co-ordinated and correlated".[17]

A good teacher can share the responsibility of planning the projects with the students. He may even let them commit some mistakes and blunders just to keep them conscious of the need for alertness and for critical examination of every step. He lets the scheme of action for self-criticism and submits it for the criticism of his experienced colleagues so as to make his plan perfect. At any rate, no project should be undertaken without sufficient early planning however experienced and resourceful the teacher be. It is better that the students also have a copy of the plan in detail.

3. *Execution*. It is here that the project is actually worked out. Execution is the most interesting stage for the pupils. But the teacher has to be extremely alert during this stage for the success of the project.

It is likely that some pupils may forget the ultimate objective of the project and get themselves overindulged in the working out stage, especially when it is interesting and exciting. It is the teacher's responsibility to guide them and make them conscious of the real objective. Whenever difficulties arise it is the teacher's duty to help them properly. At any rate, no project should be abandoned, partly finished. The teacher should give sufficient timely encouragement for the pupils to overcome their difficulties. He should also see that the whole group does not suffer because of the backwardness of few students. In such cases he should speed up the work of the backward children so that they may come along with the group.

4. *Reporting*. From the materials collected, the students have to arrive at their own conclusions and submit it for the discussion of the class in general. In doing so the teacher should not unnecessarily intervene. Only when a student fails to arrive at a judgement, need he offer suggestions. The judgement develops powers of critical analysis and independent thinking and also the ability to offer constructive criticism. The students have also got freedom to make suggestions for the improvement of the projects by way of additions, deletions, modifications, etc.

Example[18]

A study of factors involved in plant survival. The study of plant ecology and plant dispersal is a constant theme in most biological syllabuses. Whatever is done to make the topic practical and, to present it as a problem, it is often true that, for most pupils, it remains merely as a set of facts to be learned and remembered.

However, in a secondary school of academic type, a teacher was able to show that the subject may be explored by methods which provide some real experimentation.

The particular school had extensive grounds in which there were several soil types (a light loam, a heavy clay area and one field of a sandy nature). Gardening was a popular school activity which, as the interest spread, meant that new gardens were frequently brought into being by clearing and digging new pieces of ground

While talking to small group of boys the question of weeds arose. One boy said, "Well, I've got nothing but grass in my new plot." Others said, "Oh, well, I've got weeds", or "I've got a lot of little trees of some sort." A thoughtful boy remarked that it was curious to find such marked difference, all within close reach of each other, in the grounds of one school. Finally he said, "I suppose it's a matter of chance ; it just depends what gets there first." To this another replied, "But is it not also a question of what succeeds—you know, survival of the fittest, and all that ?"

The teacher said, "I expect you have each got whatever grows next door to your little plot." The thoughtful boy gave his usual slow smile and said, "May be, but we still have the problem though—why is 'that' where it is ? Why has Smith got trees ? And Jones got grass ?" and so on. Of course he was right. This was not a little question, about little plots, but a big question about big principles.

The obvious thing, soon decided upon, was to do something about it, not try to talk it out, but to work it out. The following brief record is presented to show how, under 'project conditions', faced with a problem which has meaning to them, pupils can plan a sound piece of work. In this context the planning is perhaps more important than the work itself, so that no reference is made to the latter. First the planning is recorded and then the suggestions and comments, taking each point in turn.

Action suggested	*Comment*
1. 'Dig over a new plot and see what comes up.'	'Yes, but we cannot tell whether the new crop comes from seeds already in the ground'. 'And even if the seeds are not in the ground already they may get in after the digging'.
2. 'Well, dig the plot and then cover it with a box in one place. Under the box you will get what was in the ground already. Outside it you will get what comes into the plot from outside'.	'No ! Outside the box we shall get what was in the ground and also what comes from outside'. 'But surely nothing will grow in the dark under a box ? Besides, it will keep the rain off, so the ground will be too dry'.
3. 'Well, instead of a wooden box, use a glass frame for a cover'.	'That would let light in, but still keep rain out'.
4. 'All right, then you will have to lift it off and water the ground every night'.	'We still have to separate what is there already from what comes in later'.

Action suggested	*Comment*
	'Surely that is just an argument by differences. I mean we only have to compare the two areas with each other. The differences between them are due to the presence of the box'.

This account need not be continued further. It is enough to show how pupils may be allowed, helped and encouraged to think about their problems. This is the essence of scientific method and the problem is more easily tackled by the project method than by the traditional methods of learning from a text-book or from set experiments.

In this particular study, the boys eventually divided up into a number of groups, each of which took a specific point to investigate. No one of the results taken by itself, would have provided a complete study of the factors, nor even of one factor involved in plant survival. Taken as a whole, however, the results did give, so far as could be expected from school work, a comprehensive story. Here again is a point of value in the project method : it emphasizes the function of co-operation in the search for knowledge.

Finally the method, in this instance, led to another important point—the need for verification. These boys produced a theory which many would have accepted at once. Fortunately one was sceptical and said it ought to be tested, a suggestion which led to a much wider study of the germination of tree seeds.

Problems in selecting the Project Method. However attractive the project be, the schools are likely to confront with many problems in accepting this as the full time method of teaching. It lays too much burden on the part of the teacher. He has to be a man with good organising capacity, and has to act in such a way that no time is wasted and no energy is misdirected. Often the problem of discipline springs up.

The selection of projects also creates some difficulty. Different children may be interested in different projects. To find out a project acceptable to all simultaneously becomes a tedious task for the teachers.

It is also difficult to co-ordinate the project work with the ordinary curriculum. The method to be successful wants a separate 'project curriculum' which cannot be followed in the Indian schools in the present set-up. If the project is followed with the traditional curriculum, there are gaps formed and the continuity of the course is lost.

Merits

1. The method works on two important principles of learning—'learning by doing' and 'learning through play way'. This makes it more natural and interesting for students. The students have to do many things, while studying, which require his active co-operation. Thus it is child-assertive and psychological.

2. A unique feature of this method is the motivation which it provides for the students. Throughout the project the students exhibit enthusiasm, vitality and resourcefulness.

3. If conducted along group lines, the method has values of socialisation and if arranged as individual projects, it infuses in students, qualities of perseverance, self-reliance and independent thinking.

4. As the students have to arrive at their own conclusions, they get training in critical thinking and impartial judgement. Because he has to discuss over the results of others, he also gets training in assessing the work of others.

5. After undertaking the projects the student has to refer to many sources for finding out facts relevant to the projects. This gives him training in the use of reference materials.

6. The project method has disciplinary value as well. Because no project is allowed to be discarded partly finished, it disciplines the students to complete anything that is undertaken, which has tremendous implications in everyday life.

7. Individual differences are taken into consideration. The individual has freedom to work at his own rate and speed. Similarly, the method is better adaptable to differences in aptitudes, attitudes, requirements, etc.

8. It develops qualities of self-confidence in students. As they undertake and finish projects by their own, they have a sense of appreciation about their own intelligence which develops self-confidence in them.

9. The method integrates the head, heart and hand, which many of the other methods fail to do.

Demerits

1. The project method is very expensive and is not practicable in financially poor countries.

2. The project is also time consuming.

3. The whole syllabus is not vulnerable to this method. Therefore the students get better ideas about certain fields, from where they undertook projects to the neglect of many other areas.

4. A proper understanding about the subject matter is not developed. Total amount of knowledge acquired by an ordinary child through this method, is only less than that acquired by the effective use of textbook.

5. When this method is followed, the subject matter approach becomes difficult. This requires the teachers to be versatiles.

6. Gaps in the knowledge exist. This has to be filled by the lecture method.

7. Because of the many internal adjustments to be made in the school, progress will not be systematic. This makes it difficult for the pupils to shift from one school to another during the course.

8. As some projects fail to bring about sufficient correlation, there is a temptation for forced correlation between various subjects.

9. On many occasions, both teachers and students get too much indulged in the projects forgetting that they are only means and not ends by themselves.

10. At the higher stages this method is not advisable. Then courses are to be framed according to the logic of the subject and these generally, cannot be undertaken as projects.

Though in the present set-up of the Indian Schools, it is difficult to follow the project method, there is scope for it in the science club activities. The science clubs of all schools can undertake construction projects, excursion projects, etc. All the outcomes of the projects can be exhibited during the school exhibition. During this exhibition, students who have undertaken the projects can explain to others what it is, how it works, etc. This has much impòrtance as the parents and the society are likely to be inclined to show more interest in the school activities.

E. The Dalton Plan

This method had its origin in the year 1920, when it was first introduced by Miss Hellen Parkhurst in the Dalton High School of Massachusetts. It is also often called as Dalton Laboratory Plan, since the classrooms are considered as laboratories or workshops. It was a challenge to the then existing traditional system of education which practised collective instruction, taking the class as a single unit. Collective instruction is based on three false assumptions.

1. All the children are equal in their ability and aptitudes.
2. They would respond and react similarly to the same instruction, and
3. They would progress at the same rate approximately.

Morecover the teachers were the dominant factors and they imposed their knowledge on a set of passive recipients. The rigidity of the time table and the mode of working of the class put the child under too much restrictions. All these definitely were unpsychological and therefore attempts were made to individualise instruction. Madam Maria Montessori had already evolved a scheme of individualising instruction of young pupils. The Dalton Plan goes a step further and applies those principles into the higher stages of education.

The Dalton Plan is an improvement on the three poles of education ; the student pole, the teacher pole and the subject

pole. It liberates the child from the shackles of the time table and the monotony of the classrooms. The classrooms are converted into subject laboratories where everything necessary for the study is kept for use. Indeed, Miss Parkhurst regarded the school itself as a sociological laboratory, where the pupils are experimenters and where community conditions prevail as they prevail in life itself. There are specialised teachers in these subject laboratories who are ready to render help whenever necessary. The child has got freedom to move from one room to another or to work at the subject he likes.

The whole year's work is divided into so many sub-units. Each pupil has to finish all these units before the course is completed. The pupils are first given assignments in the various subjects to be completed within a specific period. For this, he has to enter into a written contract with the teacher. He is given the next series of assignments, which he can select according to his interest, only after the successful completion of the assignments already given to him. The progress of the students is measured and is recorded in graphs which they can refer and understand where they are.

The teacher is to act only the role of a guide here. He should not unnecessarily intervene with the learning of the child. But it is his responsibility to keep an atmosphere of work in the laboratory and provide information regarding the use of some equipments. If he feels strongly so, he can also suggest effective means of attacking particular problems or can offer explanations to reveal the relevance of a point to the general principles of the subject.

The students have perfect liberty to proceed according to their own speed. The clever students can cover more assignments in shorter time and can finish the course earlier. Weak students can proceed at their rate, consume more time and finish the assignments in a longer period. Evidently no one fails in this method.

The method though is highly individualsitic has some provisions for group work, where co-operative work gives better results, and for class conferences.

Merits

1. The chief advantage of the method is in the change of attitude that it brings to the child with regard to his work. The child feels to be a responsible person, after entering into the contract with the teacher. This results in good discipline.

2. The method caters all children with different Intelligence Quotient. The clever boys can progress quickly and the dull boys slowly and all get satisfaction that they have worked at their own pace.

3. For the clever pupils, this method is even better. There is provision for providing these pupils with additional assignments to meet the need of their varying abilities.

4. Children, who are poor in certain subjects, can devote more time on these subjects and seek special guidance.

5. Since the assignments are well graded, they meet the need of the varying abilities of children.

6. Absence of a student for some time does not cause a serious break as the pupils can easily make up for the lost time.

7. The co-operative work in the laboratories makes him feel a member of the responsible community. He gets socialised by the interaction of the groups working in the laboratory.

8. The conferences and oral lessons are welcomed by the students. Home work becomes really useful for the weak child for it would help him rectify his shortcomings in the particular subjects.

9. The method is based on the principle of 'learning by doing'. As the child works at his own responsibility, he gains confidence in facing new situations and develops in him a sense of self-reliance.

Demerits

1. Too much responsibility is thrown at the shoulders of immature children. Many of the children cannot do the assignments without the help of the teacher.

2. Children are too young to be left to themselves for long. They are unstable and cannot concentrate on one thing for a long period, unless there is some external source compelling

them to do so. Anyhow this drawback is not found with university students.

3. The method encourages work-shirkers. When there is no one to compel students, they conveniently postpone their work *sine die.*

4. Lack of time table results in the want of definiteness in the school programme.

5. The method minimises the importance of direct instructions and thus denies the opportunities of hearing the 'living voice' of the teacher to students.

6. Lack of availability of teachers specially trained for this method makes its application impossible. The teachers are expected to be versatiles.

Even on very small scales, this method cannot be practised in India, because of the heavy investments necessary. Even if the whole of India tries, she cannot establish so many Dalton schools, not to speak of its applicability in cheap mass education.

F. The Winnetka Plan

The exponent of the Winnetka Plan is Dr. Carleton Washburne. In this method almost all the principles of the Dalton Plan are accepted with slight deviations. It has three guiding principles.

1. All children have to master certain facts and skills useful to them in their later life.

2. Every child must live fully and happily as a child during his educational career for, only then can the individual develop to his full capacity.

3. Every individual must have strong social consciousness to promote the welfare of the human society.

The curriculum of the Winnetka plan has two parts. The first part consists of the essential facts and skills like the three 'R's. This is common to all pupils. The second part is creative and socialised activities. This is based on individual aptitudes and interests. Though all children must master the first part, each child can proceed at his own pace, taking as much time as he needs to complete the various subjects. As children differ

in their ability, class teaching is discarded and individual instruction given. Thus the plan combines systematic instruction with the principles of the project method.

The whole year's work is divided into units called 'goals'. The children can work with a complete set of self-instructing books individually. These books are so prepared that self-evaluation also is possible. After finishing one section, he can proceed to the next section of the subject regardless of his proficiency in the other subjects. Thus a pupil can work in lower grade in one subject and in a higher grade in another subject. The first part of the curriculum includes, Arithmetic, Language, Reading, Spelling, General Science and Social Studies. The teacher is always there to help and guide. Though the details are mastered by self-study, new topics are generally introduced by discussions. The principles learnt under part I, are put to use in Part II of the curriculum. On these sections there are usually group activities and activities of self-expression. Expression, in the Winnetka schools, is considered to be the overflow of rich experience. The students have a wide choice with regard to creative activities. They plan to work and carry it through, by co-operative work. Team games and music are also included.

The school is run on self-governing lines. Pupil committees are formed which are in charge of the whole organisation. Every pupil gets a chance of serving in some committee or other.

Though Dalton and Winnetka Plans aim at individualising instruction, and are similar on many points, they differ in certain respects. The Winnetka Plan has no class conference or group co-operation, both of which are largely used in Dalton Plan. Here the pupils are encouraged to study absolutely by themselves. In the Winnetka scheme each project is learnt by itself whereas correlation is possible in the Dalton Plan. The Winnetka Plan allows the child to be in different grades in different subjects and thus the idea of a formal class or grade is thrown over-board.

Merits

1. As the method works on auto-education lines, the learning is effective.
2. The problem of failure is avoided since earlier or later the children master the essential subjects.
3. Children get more time for social activities.
4. The children are at liberty to progress according to their ability.
5. The school is adjusted to the child.
6. The students get special occasions to develop their special aptitudes when engaged in creative activities.

If properly treated, the method brings no disadvantages at all. But because of the individualised nature of instruction with its corresponding financial implications, the method becomes unpracticable in India.

G. The Assignment Method

The Assignment Method has adopted many good aspects of the Dalton Plan and Winnetka Plan. As is evident, these two plans, because of their heavy financial implications, cannot be followed as such in India and such other economically backward countries. But the Assignment method, because it includes all the major principles of the above methods and still remains 'cheaper', is more practicable.

In this method, the whole syllabus in a subject is divided into so many connected weekly portions or assignments. Each assignment is taken one by one. Detailed instructions regarding its study are provided to the students. They are asked to refer a particular textbook and answer some questions given to them. These questions are given just to see whether they have really read and understood the topic. The answers are submitted for correction to the teacher one day before the practicals are to be done. The teacher examines the answers and points out mistakes, which are to be corrected in the presence of the teacher himself before the practicals. As for the practicals, detailed instructions are provided regarding precautions, fitting up, taking readings, etc. Names of the success

ful pupils are entered in a progress chart. A record of the practical work is maintained by each student.

Some periods are set apart by the teacher for conducting demonstrations or for supplementing pupil's work, which he considers will be too difficult for the pupils to perform. It is pointed out that unless this is done, knowledge from the practical work remains shallow and nebulous.

The success of this method depends upon the properly drawn-up assignments. The practical work must not be attempted in complete isolation from the theory. Theory and practicals should go hand in hand. L.G. Dass puts forward some suggestions regarding assignments[19].

1. An assignment must be based on one textbook.

2. The assignment should state what portions of the textbook are to be read. At the same time it should draw attention to particular points, give explanations of difficult points (in some cases even a paraphrase), and it should indicate those portions of unnecessary matter which the pupil may omit from his reading.

3. Questions should come next and must :—

(*i*) be designed to test whether the student has read and understood the portions assigned.

(*ii*) not require lengthy answers.

(*iii*) frequently require diagrams to be drawn.

(*iv*) ask for a list of apparatus for the coming laboratory work.

4. Extra reading. The teacher should indicate portions of books dealing with the same or allied topics. If possible more than one book should be mentioned.

5. The part of the assignment referring to practical work must include :—

(*i*) What the teacher would ordinarily say in giving instructions.

(*ii*) The method of recording results.

(*iii*) The precautions to be taken, etc.

(*iv*) a diagram to illustrate the setting up of the apparatus if necessary.

(*i*), (*ii*), (*iii*), and (*iv*) above may frequently merely refer students to text-books.

The method throws much responsibility upon the teachers. They have to supervise almost all activities of the pupils. No student should be allowed to do the actual practical work before the preparatory work has been done to the satisfaction of the teacher. When the practicals are being performed, the teacher should move about in the laboratory, and offer individual suggestions whenever necessary. All work in connection with the experiment should be performed in the laboratory itself. If not complete, the student should come to the laboratory in his spare time and finish it. The students should not be allowed to start new experiments, unless they do the old ones to the satisfaction of the teacher. All the apparatus should be washed and kept in their original place, before the students are allowed to leave the laboratory.

Merits

1. The students are allowed to develop as self-responsible individuals, since the burden of work is on the pupils.

2. As there is a progress chart of their own ready for reference to the pupils, they can soon understand where they are. This results in a healthy competition among the students.

3. The habit of extra reading is promoted. The pupils have to read books other than text books for the successful completion of the assignments.

4. The method caters for individual differences. Bright and retarded students can progress at their own pace.

5. The teacher gets a better understanding of the pupil, which helps him to give better guidance.

6. As the progress of the students varies, very soon they will be doing different experiments at the same time. Therefore large numbers of one type of apparatus are not necessary.

7. The emphasis is more on the practical side of science. This enables the child to master many skills essential for science.

Demerits

1. As stated before, the success of the method depends upon well drawn-out assignments Many teachers find it difficult to draw good assignments, nor do they have time and patience to do this work.

2. Students are provided only instruction sheets for the assignments.

3. The teachers are put to a lot of work.
4. The method is time consuming.
5. The students are tempted to copy the answers of others.
6. The pre-requisites of the method are a well equipped laboratory and a good library. Both of these are only very rarely available in our secondary schools.

Yet on many topics which require only inexpensive and simple experiments, this method can be practised. Anyhow at the college level this will be more successful.

Example[20]

Below is given an example of an assignment on the preparation and properties of oxygen gas.

Preparation

Read paras 30—4 on pp. 51—5 of 'A New Matriculation Chemistry' by Ghansham Dass. Note carefully the caution on p. 53. Answer the following :

1. What is the best method of preparing oxygen in the laboratory ?

2. What precaution will you observe when you finish collecting the gas ?

3. What are the important properties of oxygen ?
4. Name the articles you will require for the preparation of oxygen and for testing a few of its properites.

Extra study

1. Achievements of Chemical Science (by J.C. Philip) pp. 93—3 describes the use of oxygen for rescue work in mines.
2. Readable School Chemistry (by J.A. Cochrane) pp. 50—2, describes the methods of manufacturing oxygen on a large scale. You may also study paragraph 35 of 'A New Matriculation Chemistry' for the same purpose.

Laboratory work

1. Fit up the apparatus for the preparation of oxygen gas....Give special attention to the following points.

(*i*) The test-tube must slope slightly, mouth downwards.

(*ii*) Wrap a piece of paper round the test-tube if the clamp is not supplied with a cork.

(*iii*) Clamp the test-tube near the cork end.

(*iv*) Make sure that the water well covers the beehive shelf.

(*v*) See that the jars are full of water.

2. Grind together in a mortar about half a test-tube of potassium chlorate and a quarter of that quantity of manganese dioxide. Put the mixture into the tube.

3. Heat the mixture, starting at the cork end and gradually moving the flame backwards.

4. Collect four jars of the gas after allowing the first few bubbles to escape as they are pushed out of the tube by oxygen.

5. Take hold of the retort stand and lift it till the delivery tube is out of water. Now put out the flame.

6. Test the following properties of the gas :

(*i*) Colour.

(*ii*) Smell.

(*iii*) Does it support combustion ?

(*iv*) Does it burn ?

(*v*) Its effect on the two kinds of litmus paper.

(*vi*) Its effect on burning sulphur and glowing charcoal.

Write down the results of the experiments in your note book and draw a neat sketch of the apparatus on the left hand page of the note book.

H. Programmed Learning

Programmed learning is the latest addition in the auto-instructional approach. It is not a new idea of our times since the Dalton Plan and Winnetka Plan had already experimented with self-instructional techniques. But the programmed learning is more recent and is based on the experimental findings in the psychology of learning and the effect of reinforcement.

"By programmed instruction we mean the kind of learning experience in which a 'program' takes the place of a tutor for the student and leads him through a set of specified behaviours designed and sequenced to make it more probable that he will behave in a given desired way in the future, in other words, that he will learn what the program is designed to teach him."[21]

Experimental psychologists point out that the positive reinforcements that the students get in the ordinary classrooms are few and far between and often too late to be effective. To rectify this defect, the breaking up of the content materials into tiny bits with provisions for immediate reinforcement of correct responses is advocated. Some special features of this programme include :

(*a*) Presentation of subject-matter to the learner in small, easily absorbed steps,

(*b*) Careful, sequential and logical ordering of steps called frames,

(*c*) Presentation of a question or some other stimulus (prompts or cues) concerning each step, requiring an active response by the learner.

(*d*) Immediate knowledge (reinforcement) by the learner regarding the appropriateness of his response.[22]

It is possible to programme any thing that can be verbalised. Programmed textbooks, workbooks and teaching machines are becoming very popular in U.S.A., U.S.S.R. and England. In India, the Indian Association of Programmed Learners is doing much in this direction.

The amount of information presented at each step is very small. Therefore the pupils can learn bit by bit. But teachers should not forget that all goals of teaching science cannot be realised by Programmed instruction. "However, science teachers should realise that these psychologists are usually discussing elementary arithmetic, spelling or foreign languages in which responses are labelled right or wrong. The present stage of our knowledge in science does not permit so ready a classification of answers and there is no evidence that computer-type responses should be the ultimate goal of the science program".[23]

Example

The following is a simple example of programmed procedure[24] :

Matter is made up of atoms.

Table is matter. So table is made up of...(atoms)

Similarly, brick is matter.

So brick is made up of........................(atoms)

Each of them occupies space and possesses weight. Therefore matter occupies... .....(space) and possesses.........and so on. (weight.)

Merits

Some advantages of Programmed Instruction are the following :—

(*a*) the individualisation of the rate of learning,

(*b*) the improvement of the reinforcement factor in learning,

(*c*) the increase in the rate and amount of learning,

(*d*) the improvement in the efficiency and quality of learning,

(*e*) the improvement of pupil's attitudes towards learning through the individually perceived success factor (immediate feed back).

(*f*) the development in pupils of a sense of personal responsibility for their own learning progress.

(*g*) the improvement of evaluate criteria and processes in schools and

(*h*) the freeing of teachers from many of the tasks which have perennially limited their time for such creative activities, as careful planning, reading and more effective guiding of pupils' learning activities.[25]

Demerits

But Programmed Instruction has many limitations as well. The principal disadvantages that have been advanced are :

(*a*) a machine can't take the place of a teacher,

(*b*) automated teaching is boring and offers no challenge.

(*c*) automated teaching will make robots out of pupils,

(*d*) there is no feed back between student and teacher in the learning process,

(*e*) automated teaching is more trouble than it is worth,

(*f*) the machines cost too much, and

(*g*) there is a shortage of well-developed programs in most fields.[26]

Teaching machines : Teaching machines form part of programmed learning. They are working on the principle of the computer and provide immediate reinforcements at a rate impossible for the class teacher. Many of the secondary school science and mathematics topics can be taught with the aid of computers. "In primary and secondary school mathematics and science, course materials can be incorporated that will allow the computer to make its unique contribution to the teaching process, that of allowing the student to solve by numerical methods problems which are too advanced for him to work with by analytic means, and bringing to him insights that are difficult to attain in any other way."[27] The teaching machines need not be of the computer type always. A set of well programmed 'flash cards' can also become a teaching machine in the hands of a good teacher.

I. The Developmental Method

The Developmental method is generally followed in the schools of India for various reasons. Till recently it was followed as such ; but the present tendency is to integrate it with the Unit method.

The name of the method was suggested by Hunter. It is an inductive method where a problem is solved by the whole class under the guidance of the teacher. The teacher asks suitable questions, elicits answers from the students and thus builds up the lesson. The method has its origin from the Herbartian school and has five formal steps, preparation, presentation, comparison or association, generalisation or definition and application.

The *preparation stage* is meant for preparing the minds of the students for the acquisition of new knowledge. This is generally done by asking suitable questions from the previous knowledge of the pupils which have relevance to the new knowledge to be imparted. This naturally motivates the child and his interest is aroused and sustained. Sometimes simple and interesting experiments are performed to motivate the students.

The narration of interesting anecdotes about scientists and their inventions, etc., if relevant to the portion, will also serve the purpose. Generally a problem evolves at the end of the preparation stage.

It is during the *presentation stage* that actual teaching takes place. Here the new knowledge is linked up with the old one. The success of presentation usually depends upon the oral questions of the teacher. Sometimes demonstrations are performed. A good display of aids, materials and specimens are there. There is constant interaction between the teacher and the taught. The students are provided with as many sensory experiences as possible. Sufficient training is given for them in inductive and deductive thinking and for scientific mindedness in general.

During the presentation stage, the students have to compare, generalise and apply. *Comparison* becomes inevitable when the class deals with more than one thing. *Association* also has to be made with the previous experiences of the child. The next stage of comparison is generalisation. From the various particular examples they have studied, they make generalisations. But generalisation is possible only when more than one thing is dealt with and when there is provision for comparison.

This is followed by the next step, namely, *Application*. Here the simple generalisations that they have arrived at is extended to particular areas. Application is also the sure test of good understanding.

When this method is applied to actual classroom teaching there is some difference in the steps followed. The new steps are, *Preparation*, *Statement of aim*, *Presentation*, *Recapitulation and Assignment*. The statement of aim is made before the presentation starts. This is made in clear cut, simple language, and this helps the students to understand the objectives of the lesson. During the recapitulation stage, the teacher asks questions from the day's portions (which has already been taught), to verify whether the students have understood what he has taught or not. Good response at the recapitulation

stage means that the lesson was successful. The assignment should suit the pupils in all respects. Generally it is given as home assignment.

Merits

1. The method is economical. This does not need an expensive laboratory or an extensive library for its success.

2. It is time saving. Neither the teachers nor the students need waste their time in projects, problems, discovering things, etc. The portions can be finished in time.

3. The method follows a multiple line of approach. All senses are kept engaged and therefore knowledge gained is retained for a longer time.

4. The method has socialising value. There is constant interaction between the teacher and the taught and among the students themselves. This smoothens gradually the personality of the child.

5. The teacher gets a better understanding of the child. Because there is close interaction, he gets a closer view of the child and this enables him to give better guidance.

6. The method is psychological. Every student gets the satisfaction that he or she has contributed his or her mite to the building up of the lesson. There is also scope for better immediate reinforcement.

7. The method stimulates thinking, and develops problem-solving skill, especially if the teacher is skilful.

Demerits

1. Though it is a child-assertive method, the success of it largely depends upon the teacher. It is his logical, thought-provoking questions and his way of handling students that prove whether the method is successful or not. In the hands of inefficient teachers, the method usually fails and the whole class procedure becomes a tedious monotony for the child.

2. Many of the skills of science are not developed in children. As there is no provision for laboratory experiences, the laboratory skill, the manipulative skill, the observation skill, etc., are not developed in children.

3. The method does not cater for individual differences. It is not the child, but the class which is the unit of instruction.

4. The method makes no provision for the retarded pupils. Unless the teacher is specially alert, all questions will be answered by the bright pupils. This will have unpsycological effects upon the retarded.

J. The Unit Method (Unit Plan)

The term 'Unit method' is really a misnomer. It is more a pattern of planning and organising teaching than a method by itself. The techniques of all other methods like lecture, demonstration, project, problem-solving, etc., and also the Herbartian steps may be called for in a unit plan. The method became very popular in America from the very beginning of this century. In India many states have switched over to the unit plan recently.

A unit plan is composed of both method and content. It includes the method of presentation and the matter to be presented. The method is highly flexible and can incorporate the spirit of all other methods. The actual teaching according to the plan has three stages, the *introduction*, the *presentation* and *conclusion*. The introductory stage is meant for preparing the mind of the students and for motivating him, the presentation for actual imparting of knowledge through meaningful experiences and the conclusion for organising and reviewing the knowledge acquired.

The unit plan has a structure of its own. Here the content for the year is divided into monthly units, monthly units into weekly units and the weekly units into the day's unit plans. Each day's lesson though has certain distinct features, is not a solely independent unit. It has a definite role to play in the development of the curriculum. There is no definite method for presenting a particular content area. But the method insists on the most suitable learning experiences to be provided for the pupils. Thus there are Problem units, Unit Projects, Contract units, etc., emphasising different kinds of experiences. "There is no stereotyped pattern for the development of a teaching unit, every thing depends upon the nature of the sub-

ject matter, the background of the pupils, and the conditions under which the unit is taught."[28]

The unit plan may have the following elements.

1. Motivation.
2. Overview.
3. Inventory of background.
4. Presentation of new experiences.
5. Organisation of learnings.
6. Summarization.
7. Drill.
8. Review
9. Evaluation.[29]

The motivational phase reveals to the students what they will be doing as the lesson progresses. Motivation should be from within and should not be enforced from without. The overview helps them look ahead and plan their procedures in accordance with that. It enables them to see the scope of the material they have to master. The inventory of the experience background of pupils is of much importance. This helps the teacher to understand where his pupils are, and modify his techniques accordingly. Both direct and vicarious experiences can be provided during the presentation of new experiences. But first hand experiences should always be preferred. There should be variety in the experiences provided. The success of the whole teaching is centred around this phase. The organisational phase provides opportunities for pupils to organise their learnings in their own way. This though won't yield conventional results, brings more meanings for the pupils. Summarization is often needed at the end of the teaching unit. It should be by the pupils also and not always by teachers. Organisation and summarization sometimes go hand in hand. Review and drill check forgetting. If the point to be mastered is important, then review and drill are always advisable. Evaluation helps self-assessment and self-improvement. It is not at the end of the unit, but is a continuous process and runs throughout the lesson.

The two important factors of the unit plan are content and the learning experiences. Regarding the selection of the content, in the Indian circumstances, the teachers enjoy practically no freedom at all. But they can organise it and present it in a novel way. An ideal 'content area' makes provision for many learning experiences to be provided. It is useful and related to the life of the child. But the content should not be too elaborate and complex. It should be limited and simplified to suit the intelligence of the child. Learning experiences enable the child to acquire knowledge, develop understandings and skills and also the scientific mindedness. For this there should be a variety of experiences provided. This also is determined by the nature of the content and the objectives and specifications of the unit. A good teaching plan continuously evaluates the whole teaching learning procedure too. This also helps for immediate diagnosis and remedial teaching.

The Unit Plan is generally presented in four columns : the content, the objectives and specifications, learning experiences and evaluation.

Content	*Objectives and specifications*	*Learning experiences*	*Evaluation*
Introduction			
Presentation			
Conclusion			

The columns need not be in the order given. Sometimes one or two columns more are added by splitting objectives and specifications and also by adding a new column for the teaching aids. Whatever may be the number of columns, it is the objective based nature of teaching which distinguishes the unit plan from other programmes.

K. Group Methods

This is not a method by itself, but only a technique of instruction. Group work has many advantages in science

teaching. In fact at the college level, in connection with the laboratory experiments, group work is often practised. But group work has scope in all areas of science teaching.

The following are the outcomes of group work.[30]

1. Allows full participation by the individual.
2. Gives maximum direct experience, with materials.
3. Provides for wide range of interests.
4. Provides for wide range of talents.
5. Permits close matching of assignments to abilities.
6. Takes advantages of adolescents' desire to work together.
7. Gives shy and retiring pupils increased security.
8. Gives practice in democratic processes.
9. Helps pupils explore their leadership potentials.
10. Provides a change from standard classroom techniques.
11. Helps teachers become better acquainted with individuals.
12. Helps teachers find time for special help for individuals.

The teacher should study his pupils carefully before grouping is done. At the pre-adolescent stage, pupils dislike being grouped with the opposite sex. Similarly, they reject to work in the company of others whom they dislike. Proper care should be taken in the case of permanent trouble makers. In fact group work provides them with additional opportunity for mischief-making. The teachers can put them in some suitable groups and watch closely. Each group can have a leader acceptable to the whole group. All the members should be engaged throughout in one activity or other. Some groups may finish their assignments earlier. They may be provided with additional assignments.

With all these precautions, sometimes the group work may prove a failure because of the immaturity of the students. But even in such cases, it is of real help to the child for it socialises-him very much.

The larger the size of the group, the greater the organi sational problems. But they provide a more realistic social structure. Additional assignments can be provided to those

groups which finish their assignments earlier. For children having special talents also additional assignments in their respective fields may be given. The group work can be a really useful activity with exceptional children. They can be detached from the general class and additional group work assigned.

These methods have not become popular with teachers of science in India. But some language teachers are practising it. It is time that science teachers also experiment with group methods.

Summary

The Discovery Approach stresses more on learning, than on teaching. Children have to find out things for themselves. Science is considered more as a process and therefore stress is on the development of scientific mindedness. There are many child-assertive methods. The Experimental method, Project method, Dalton Plan, Winnetka Plan, Assignment method, Programmed learning, Developmental method, etc., are only a few among them. Unit method is more a method of planning lessons and group method is only a technique of instruction. All of them have their merits and demerits. A teacher should select a method, most suitable for the content, so as to get the maximum results

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CHAPTER XIII

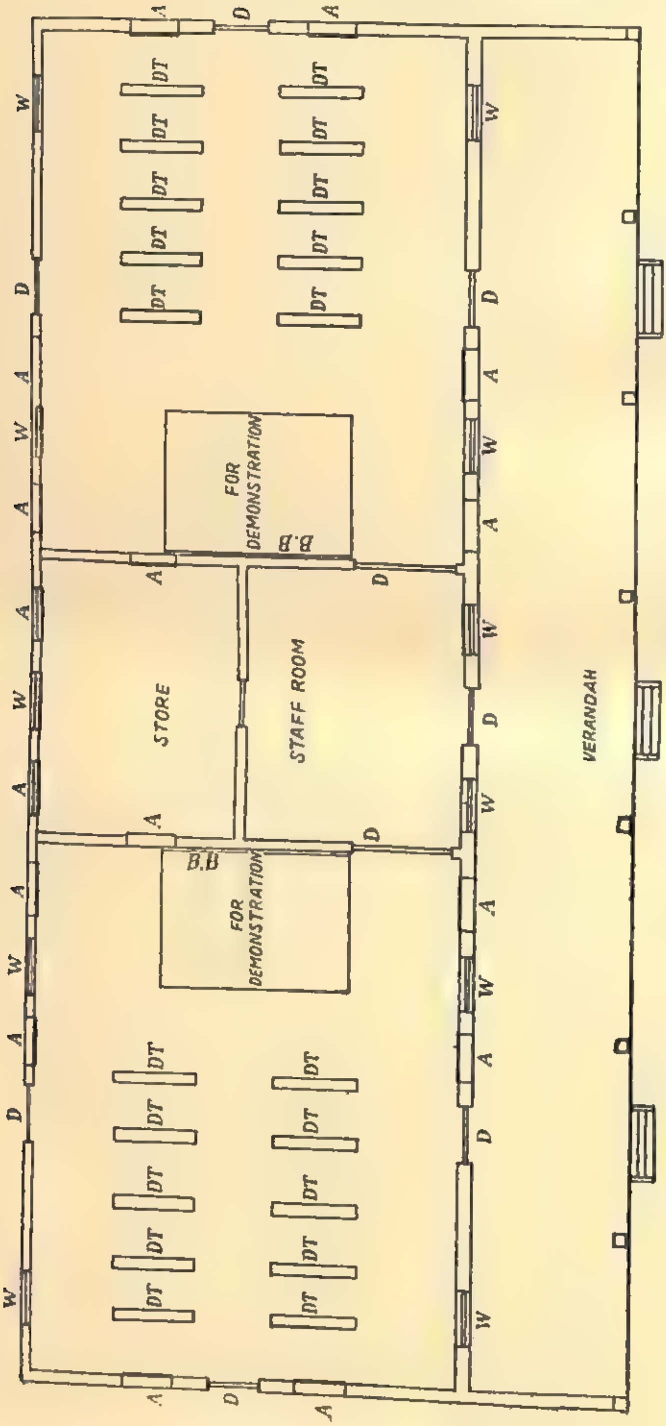
AIDS TO TEACHING SCIENCE

All the popular teaching aids like charts, maps, models, dioramas, films, film strips, slides, graphic representations, etc., can be used with great advantages in the teaching of science subjects also. But there are some special teaching facilities which are highly essential for the proper development of science lessons and for the realisation of the major objectives of science teaching. Such aids and facilities having additional pertinence to the teaching of science alone are dealt with in this chapter. The laboratory, science clubs, science fairs, scientific excursions, etc., are only some among them.

1. The laboratory

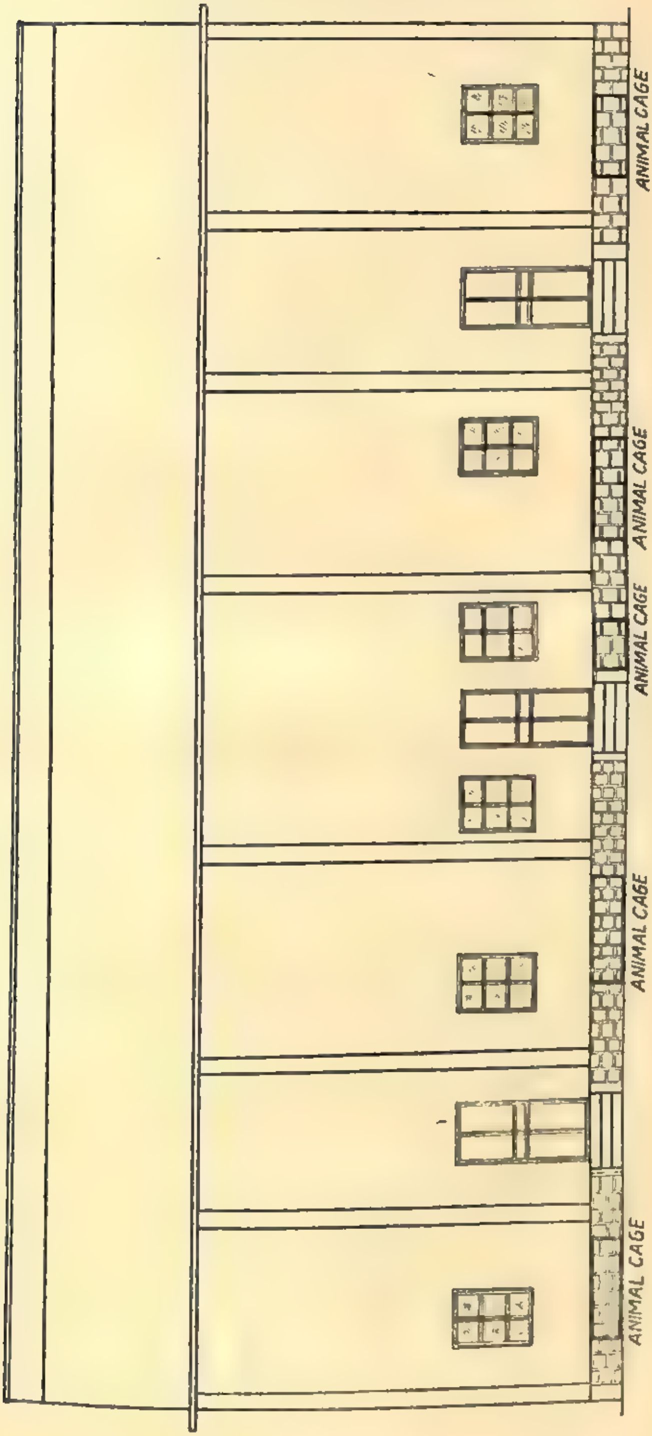
Science teachers of India cannot be very ambitious about their laboratories because of economic reasons. Thus many laboratory plans proposed in foreign books cannot be accepted in India because of our poor financial set up, nor are they really inevitable for our schools. We are not following the individual laboratory method at the high school stages. Therefore, laboratory is more a place of experiments by the teacher than by the students. Even when we switch over to experimental method (if at all we do it), the topics for that are so selected that they need not call for difficult experiments needing complicated arrangements. Thus a simple demonstration room, vulnerable for experimental method will suit the Indian conditions best.

The plan proposed in this book is simple, but has many advantages and most convenient for our schools. It has two demonstration rooms, one staff room and one store-cum-preparation room. Obviously this is not an ideal laboratory, but willl serve the most essentials. The two demonstration rooms are so furnished as can be easily converted into rooms for



Plan of the Laboratory.

A—Almirah (in-built)
BB—Black-board.
D—Door.
DT—Student Desks.
W—Window



Front view of the Laboratory.

experimentation. Though some difficulties may arise due to the lack of many of the costly equipments like water taps and sinks at each desk, drainage arrangements, cup boards, fans, etc., this plan includes the minimum essentials for a switch over to the experimental method and the teachers can make improvements upon this as and when funds are available. It is better to remember that "a science room is never so good that it needs no changes—or so bad that it must be abandoned as hopeless."[1]

The demonstration rooms of the proposed plan can accommodate fifty students each, either when they see a demonstration or engage themselves in experiments. (Generally in India a class consists of about fifty students.) The room can be used for science club activities also. Only the demonstration table has water taps and sinks. (In schools where water supply is not available, water buckets may serve the purpose.) The students' desks are generally kept folded, when the demonstrations are going on, but for experimental purposes they can be easily converted into broader tables. (This is possible by something like the sofa-cum-bed arrangement.) There is a small room in between the two laboratory rooms. This is separated into two comparatively smaller rooms by means of a curtain or a thin wall. One can be used as the staffroom for science teachers and the other as the store-cum-preparation room. Only valuable chemicals and those which involve danger and require caution need be stored in this room. Others can be stored or displayed in the demonstration rooms themselves, in the almirahs and show-cases built inside the walls. (This minimises wastage of space.) The rooms have ceiling, if possible, with fire proof materials, and painted, preferably with light colours. Arrangements are also made for good lighting and proper ventilation. There are also provisions for making the room completely dark, for performing and demonstrating optical experiments. Rooms have four doors each, all opening outwards so that in case of an accident, students can escape suddenly.

Some living specimens (both animals and plants) also can

be brought up in cases specially built for the purpose and placed in the corners or near the windows of the classroom as are necessary. A botanical garden can be made in the land area around the laboratory. If the laboratory is having concrete roof, then a botanical garden can be had above the roof also. This may also give the building a better appearance. If small cells can be constructed in the corridore of the building, many living animals can be brought up in them. If incubators, sterilizers and refrigerators are available they may be kept in the store room.

The laboratory being a place of potential dangers, both teachers and students should be very careful while engaged in laboratory activities. The freedom of the students has to be considerably restricted. The laboratory should have fire extinguishers and first aid boxes.

Improvisation of apparatus. "The poor teacher complains, blames lack of equipment for the dullness of his lessons, and allows his pupils to revert to the dull monotony of note taking and passive learning of the text book. The good teacher, however, finds in the same circumstances a challenge to his ingenuity."[2] However well equipped a laboratory be, it may lack some pieces of apparatus that are most essential in conducting experiments. But the construction skills of both the teacher and the taught if put to good use, can improvise many apparatus which can be used more advantageously than the sophisticated ones. Students are more attracted by them as they were involved in their construction. Knowledge of subject matter also gets deepened and grows to the application level. Much money can be saved and some complexities of sophisticated appliances avoided. The UNESCO Source Book for Teaching Science gives detailed instructions for the construction of many equipments in science. 'Science Teacher's Hand Book' published by the American Peace Corps also contains many suggestions. Some hints for teachers and pupils for improvising equipments are given below.[3]

1. Flasks and beakers from old electric bulbs.
2. Radio coils from wire and used cereal boxes.

3. Simple telescopes from dime store lenses and mailing tubes.

4. Simple telegraph sounder from bolts, wire, and a cigar box.

5. Simple telegraph key from pieces of scrap copper, a bolt and a wooden spool cut in half.

6. An insect collecting net from a coat hanger, a piece of cheese cloth and an old broom handle.

7. Insect mounting boxes from cigar boxes.

8. Insect stretching boards from cigar boxes.

9. A motor from a board, nails, and wire.

10. Simple magnets from the dime store or an old Model T Ford automobile generator.

11. Ringstand from curtain rods, staples and a wooden base.

12. Bunsen burner from a wooden base and a short length of scrap pipe or brass or copper tubing.

13. Pulleys from the dime store or hardware store.

14. Wide-mouth crisco or coffee jars for aquaria jars.

15. Olive bottles for wide-mouth bottles for collecting gas.

16. A standard compass from a dime store, hack-saw blade, a cork, a piece of glass tubing and a needle.

17. Vacuum experiments with a sink drain plunger (plumber's friend from the dime store).

18. Magdeburg hemispheres from two sink plungers.

19. Electroscope for static electric experiments from dime store rubber balloons.

20. Ammeters and voltmeters made from mounting battery, volt ammeters obtained at the dime store.

21. A simple laboratory generator from an old automobile generator.

22. Wet and dry bulb thermometer from dime store thermometers, old ink bottle, and a piece of muslin.

23. Gyroscope experiments with a dime store gyroscope.

24. Light experiments with mirrors and lenses from the dime store.

25. Storage battery from old battery acid, a jar and two pieces old lead pipe that have been flattened out.

2. Science Clubs

"The spirit of science is the spirit of discovery. Experience teaches that one of the most exciting and effective ways to impart to the students the joy and adventure of scientific discovery is through science clubs."[4] Again, "The club offers the pupil an opportunity for specialisation which he does not have in the classroom. In the classroom his work is formal, in the club it is informal; in the classroom he is told what to do, in the club he chooses ; in the classroom his method of dealing with a topic is clearly outlined by teacher-imposed restrictions, in the club programme the method is of his own devising ; in the classroom he tries to please the teacher, in the club he works for his own and his club's interests and for the joy of doing his work ; in the classroom he conforms to a system, in the club he suits his own convenience. In short the club represents freedom and expression where the classroom represents conformity and repression."[5]

The above two quotations may bring to limelight the importance of science clubs in schools. They really form the backbone of school-sponsored extra curricular activities in science. They help the realisation of many of the objectives of teaching science and convert the learning of science into an interesting hobby.

Science clubs can be of two sorts—(1) The specialised interest club and (2) The general type club. The specialised interest club, as the name hints at, undertakes only one kind of activity. The examples are the Camera club, the Nature club, the Agriculture club, the Radio club, etc. Experience shows that they are short-lived. The general type clubs undertake many kinds of activities from different areas of science. The General Science club, Biology club, Physics club, Chemistry club, etc., are examples for this type. The general type clubs fit the interests of a greater number of pupils.

The science club needs the active co-operation of the administrator. It is only with his co-operation that science clubs can effectively function. The Directors of Public Instruction of various states in India have given permission to levy a

small fee on students for the activities of science clubs. The science club can co-operate with the science laboratory also. Many things wasted in the laboratory will be of much use in the science club.

A science club should never be imposed upon the pupils. It should emerge only as a need of the pupils. The teacher can motivate them and guide them—that is all. A senior science teacher can be the sponsor of the club. He in co-operation with the headmaster can plan the club and organise it. Meister suggests the following questions to be answered while framing the constitution of the club.[6]

1. What shall be the aim and purpose of our science club ?
2. What shall be its name ?
3. Membership :
   (*a*) Who can become a member ?
   (*b*) What must a boy or girl do to become a member ?
4. Meetings :
   (*a*) When shall they be held ?
   (*b*) Where ?
   (*c*) How often ?
   (*d*) Who shall call for special meetings ?
5. Money :
   (*a*) Shall we pay dues ?
   (*b*) How much ?
   (*c*) Can we levy taxes ?
   (*d*) How ? How much ?
   (*e*) For what shall the money be used ?
6. Expelling members :
   (*a*) For what reason or reasons ?
7. The business program :
   (*a*) How long shall it be ?
   (*b*) What shall be the procedure ?
8. The science program :
   (*a*) How many different activities shall the club have ?
   (*b*) What shall decide upon and arrange these programs ?
9. Officers :
   (*a*) When shall elections take place ?

(b) How often ?
(c) What officers shall we have ?
(d) What shall be the duties of each officer ?
(e) How can an officer be impeached ?
(f) How can an officer resign ?
(g) Shall officers filling positions left vacant be appointed or elected ? And how ?

10. Any other regulations you think it important to put into the constitution :

All students of science cannot and need not be made members of the science club. Only those who have a keen interest in scientific activities need alone be admitted. Twenty to twenty-five make a convenient number. But if there is a heavy rush and all seem sincere, a science club under a different sponsor should be organised.

In the planning and execution of the science programmes, students should be given active participation. The following activities are suggested.[7]

1. Visual programs in which lantern slides, motion pictures, micro projector, or some other concrete visual aids are employed.

2. School journeys. Visits to such places as a power plant, a mill, telephone exchange, weather bureau, zoological and botanical gardens, green house, city water supply, filtration plant, modern dairy, and museums are always interesting and help to create interest in science.

3. Work periods. Some club meetings should be set aside for the members to engage in individual work such as doing experiments, preparing demonstrations, or making posters and exhibits. In some science clubs every other meeting is made a work period.

4. Current events. Some clubs devote one meeting a month to reports and discussions of new developments in science as reported in recent scientific magazines and newspapers.

5. Science spelling match. This is an old fashioned spelling bee in which only science words are used.

6. Special speaker program. Science clubs enjoy hearing occasionally, some expert or specialist such as a doctor, an engineer, a forester, or a bee-keeper.

7. Science almanac. This program usually consists of reports on famous scientists born in a particular month.

8. Science question-box.

9. Science debates.

10. Science plays.

Science club activities can be so organised to help the community in various aspects. This is very necessary in Indian conditions. If it can co-operate with the local Gramsevak, many demonstrations on health and hygiene can be given to the community. In co-operation with the Agricultural Extension Officer and officers in charge of Adult and Social Education, the science club can undertake many activities for the improvement of agriculture and for the eradication of many superstitious beliefs. The science club can also improvise many apparatus necessary for the laboratories which otherwise might be very costly.

Though the science clubs are organised mainly for the students, it is the enthusiasm of the teacher which ultimately determines its success. If he is hardworking, resourceful and enthusiastic, the science clubs won't disappear very easily.

3. Science Fairs

Science fairs have become so common in some countries because of the adoption of the Project method in teaching. But the outcomes of science club activities will also be fit for science fairs. The greatest contribution of it lies in the recognition and encouragement that it gives to the student participants.

The purposes of science fairs have been listed as follows.[8]

1. To focus attention on science experiences in school.
2. To stimulate a greater interest in science by all pupils.
3. To stimulate a greater interest in scientific investigation over and above the routine class work.
4. To provide stimulation for scientific hobby pursuits.
5. To offer an opportunity for display of scientific talent through exhibits and demonstrations.

6. To recognise and commend youthful scientific talent.

7. To provide constructive suggestions for teachers and pupils of science.

Careful planning is necessary for the success of any science fair. Several committees have to work separately and together for its success. If different schools of the same locality can collectively organise a science fair it can be made more impressive to the public. Charts, collections, models—both static and working—experiments, investigations, etc., make good exhibits. It is also possible to arrange them in such an order as to form the natural development for the science course for a particular grade. Several days before the fair, details regarding the exhibits, its nature, space it would need, additional facilities to be provided like electricity, water supply, etc., have to be called for. There should be a time schedule which should be correctly followed. There should be measures for safety also. The exhibits should be displayed in an artistic manner. The following are some hints for students which may enable them to present an effective display.[9]

1. An upright three-sided display board may be constructed which will contain the relevant facts of the project. Construction should be durable, and therefore materials which are stiff and which stand solidly—such as heavy card board, masonite, or plywood—should be used. If card board is used, it will usually require reinforcement and back support so that it will stand solidly without curling.

2. If display boards are joined, they should be securely hinged. Metal hinges can be used with heavy materials. Where card board is used, satisfactory hinges can be made with an adhesive tape.

3. The design should be started by making several rough sketches. Evaluate the arrangement of materials, lettering and detailed enlargement. This should then constitute the proposed plan for the actual display.

4. Be sure to make the design eye-catching and attractive. Remember that each project will complete with many others for the attention of the judges and visitors. It should be design-

ed so that it arrests the viewer's attention. However, gaudy, splashy, or bizarre designs should be avoided.

5. Make the display simple. Use an eye-to-follow design which can 'shout out' its message in five to ten seconds. Remember that most viewers will spend only a minute or two with each project, so be sure that they will have an opportunity to understand and appreciate the exhibitors' efforts. Be sure to avoid the use of unnecessary decorations of 'scattershot' arrangements. These tend to confuse instead of clarify.

6. The lettering should be large and simple. The titles should be short and descriptive and the narrative should be as brief as possible and to the point. It is best to use pictures, drawings and diagrams whenever possible. These are better than detailed explanations. If the written discourse is long, it should be placed in a folder like a scientific paper, rather than attempting to place all of it on the display.

7. Select colors tastefully. A single pastel shade for background coloring is better than white, which tends to appear "vacant". Dark tones should be used to accent the areas which are to be emphasized. Certain color combinations are more appropriate for some types of projects than others. For example, greens and yellows suggest the natural sciences, reds and blues the physical sciences and blues and white suggest medicine.

8. Effective use of lighting enhances a project. If lights are to be used with the project, care should be taken that no direct light or glare shines into the eyes of the viewer.

9. Unique and creative arrangements often enhance a project. Many projects lend themselves to a tiered arrangement rather than the conventional flat format.

10. The name and class of the exhibitor should be on the display board.

11. Moveable parts must be firmly attached and safe.

12. All important help should be acknowledged.

13. Certain projects may permit the public to operate the controls. Such controls should be sturdy in construction and should prominently display full instructions for their use.

As a sign of encouragement, best items may be given prizes. For this judges competent enough should be appointed. The criteria for evaluation may be the scientific approach of the exhibitor, originality, technical skill and workmanship, thoroughness, dramatic value and personal interview with the exhibitor. If organised on a collective basis, shields also may be presented to schools scoring maximum points.

4. Scientific Excursions

The excursion is an out-door activity where pupils come into first hand contact with objects and specimens. It is not a mere pleasure trip to a place of interest. But it is an objective based journey undertaken by the students under the guidance of the teacher. Visit to factories, museums, zoo, parks, etc., have high educational value.

The excursion should be conducted only when there is a felt need for it. Otherwise it may degenerate into a mere social trip. The demand for the excursion should come from the students. Excursion can be arranged as a project or as a science club activity.

The organisation of the excursion has three phases, the *preparation* phase, the *action* phase and the *follow-up* phase.

Good previous planning and thorough preparation are quite essential for the success of any excursion. While planning a number of points are to be considered by the teacher. The strength of the party is an important factor. Below twenty-five will be a handy, convenient number for one teacher. If there are more, more teachers are necessary. It is better to take different groups on different occasions. After being sure about the number of students, a study of the place to be visited is to be made. (The place should be selected by the students themselves under the guidance of the teacher.) A plan as to what are to be observed in different places is to be prepared. Then the teacher should go to the selected place before hand, make an on the spot study of the whole area to be covered, locate the probable difficulties likely to be overcome, etc., and make arrangements for meals, stay, etc., of the party. Different committees can be constituted like the transport committee,

food arrangements committee, entertainment committee, etc., to help the teacher. The whole groups can be divided into sub-groups and put under the charge of a leader. Students should be insisted to bring all the equipments necessary for their comfortable stay, for taking down notes and for making observations.

During the action phase, when the pupils are on the spot, the teacher should see that all of them are busily engaged. Haphazard movements should not be allowed. Everything should be systematic and the pupil should get maximum advantage from the trip. Whenever difficulty arises, it is the responsibility of the teacher to help them by way of offering suggestions and guidance. But the teacher should be sympathetic and should not tyrannise over them. If it is a natural science collection project, indiscriminate destruction should be discouraged. Many qualities of heart like sympathy towards living specimens, appreciation of nature, etc., can be developed through natural science projects.

The last phase is the follow-up work. It is here that the excursion is really summarised. It may take the form of submitting a report or arranging an exhibition. It is better that different groups of students are put in charge of each item like preserving, mounting, labelling, etc. If necessary a few new type tests can be administered upon the students to test whether they have really understood things or not.

Summary

All common teaching aids are useful in teaching science also. But the laboratory, science clubs, science fairs, scientific excursions, etc., are highly essential for the realisation of the major objectives of science teaching. In the Indian conditions, the laboratory is more a place of demonstration by the teacher than experiments by the students. Therefore a demonstration room which can be converted into a laboratory will be most suitable to Indian schools.

Science club activities should form an integral part of teaching science. Many activities to be undertaken by science

clubs are suggested. Science fairs can be the outcome of either science clubs or project method of teaching science. It is a good encouragement for pupils.

Scientific excursions can be undertaken occasionally. The teacher has to be vigilant during the various phases of the excursion.

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CHAPTER XIV

EVALUATION IN SCIENCE TEACHING

Examination and Evaluation

The term examination is too common to need any explanations. It comes as a shock to students of all subjects, and no system of education is absolutely free from it. "Examinations are formidable even to the best prepared, for the greatest fool may ask more than the wisest man can answer."[1] In India, the whole system of education is still under the tyranny of examination. Almost all drawbacks of our system can be traced to the domination of examinations. All educationists have condemned it, but no one could suggest a suitable alternative for it. The examinations simply assess the standards attained by the students.

But the term 'evaluation' has wider implications. It is concerned with three things in particular.[2]

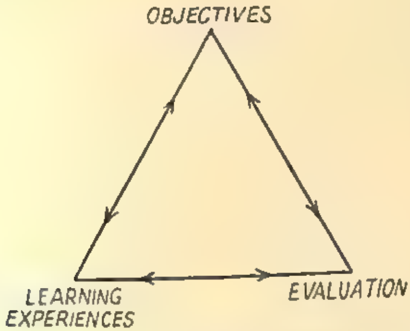
1. It will measure in every sense that tests and examinations are supposed to measure.

2. It will motivate, guide and inspire the students in the pursuit of his studies.

3. It will teach him by disclosing to him his strength and weakness, by indicating clearly his degree of progress, by showing him where emphasis needs to be placed, by training him in ways of obtaining more knowledge and by giving him practice in its application to life situations.

Thus evaluation is more than testing and examining. "It is studying and assessing achievement and growth in relation to the potential of the student and the objectives of the study."[3] It is a continuous process and is a function of both the teacher and the taught and is interwoven with other aspects of teaching-objectives and learning experiences. This inter-relation-

ship of the three aspects of teaching is usually represented in a triangular form.



What is to be evaluated ? Evaluation is closely related to the teacher's goals and points of view on science teaching. Indeed it is evaluation that provides a measure of progress towards the realisation of the objectives of teaching. In the second chapter of this book, the major objectives of teaching science are stated clearly. They are :

1. The pupil acquires knowledge of facts, terms, concepts, principles, etc , in the field of sciences.

2. The pupil develops understanding of facts, concepts, principles, processes, etc., in sciences.

3. The pupil applies scientific knowledge in a new or unfamiliar situation.

4. The pupil develops skill in drawing diagrams, manipulating apparatus, preserving specimens, improvisation, collection of information, scientific expression, observation etc.

5. The pupil develops interest in the world of science.

6. The pupil develops scientific attitude, values and qualities, and

7. The pupil develops a sense of appreciation towards scientific phenomena.

A good evaluation tool must measure to what extent these objectives are realised and thus help remedial teaching. Unfortunately, our measuring tools even now measure only the achievements at the cognitive domain, the psychomotor and affective domains being neglected.

How to evaluate ? All evidences that reveal that some objectives have been realised can be used as means for evaluation. There are a variety of them. Richardson classifies them as follows[4] :

1. What students do :

Anecdotal records of significant behavior, original laboratory developments, voluntary contributions to science resources (specimens, books, and so on), instances of laboratory resourcefulness.

2. What students say :

Class discussions, conferences, informal conversation, oral reports, Panel discussions.

3. What students write :

Laboratory reports and Notebooks, Reports of readings, Field trips, Tests and Examinations, Self-evaluations and logs of activities, Term papers.

4. What students produce :

Laboratory products and Apparatus set-ups, Displays, Collections, Photographs, Results of individual project work, Production of and/or participation in skits and plays.

5. What students read :

Depth of reading in relation to assignments, Voluntary reading of books and magazines in scientific and related fields, Newspaper reports of current scientific and technological developments.

The forty-sixth year book of the National Society for the study of Education also includes various devices that may be used for purposes of evaluation.[5]

1. Evaluation by paper and pencil devices :
(*a*) Verbal tests, either "objective" or "essay" in form.
(*b*) Diagrams, pictures, charts, etc.
(*c*) Rating scales and checklists.

2. Analysis of work products according to acceptable criteria (apparatus set-ups, note books, student collections, committee reports, etc.)

3. Classroom questioning and discussion.

4. Observation of significant behavior, either :

(*a*) Informal, as in day-by-day classroom or laboratory activities, or

(*b*) Systematic, as in situations specifically planned to elicit known types of behavior.

5. Conferences and interviews with individuals or with groups.

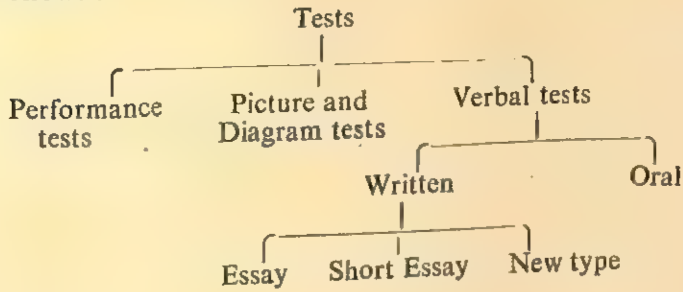
Unfortunately teachers of India generally resort to mere verbal questions for evaluating students. But a true evaluation tool will and should make use of the very life situations of the child to evaluate him. The questions will also tell upon the teachers who have constructed them. "The dull teacher sets a dull examination paper, the teacher gifted with originality produces questions which reflect his own qualities. If a teacher has set the same paper, year after year, to pupils of a certain grade, his pupils may have learned something, it is certain that he has learned nothing. An examination paper often reveals more about the teacher who sets it than about the pupils who answer it."[6]

Types of Tests

Tests in science can be broadly classified under three heads :

1. Performance tests,
2. Picture and Diagram tests, and
3. Verbal tests.

Verbal tests are of two types : (a) Oral and (b) Written. The Essay type, short essay type and New type form the different forms of written type questions. They can be represented as follows :



All types of tests have their own values and shortcomings. They evaluate the different aspects of teaching science.

A. Performance Tests

The performance tests make use of concrete materials and therefore come very close to reality. When applied to science they generally take the shape of laboratory assignments These tests successfully measure, the pupils' manipulative skill and laboratory techniques. They are made use of to measure the ability to perform certain operations in science. These tests can be of two types—one a considerably longer type which measures a lot of skills by one question (corresponding to the essay type of verbal examinations) and the other a short-type, which measures only one, skill by one question (similar to the new objective type of tests). Much research has not been done in the area of performance tests.

The examples of the short type performance tests are providing the necessary equipments and asking the students to make connections so that an electric bell may ring, or providing two solutions and asking them to titrate. Giving a salt and asking to analyse it, or requesting to find out the equivalent weight of a metal or asking the students to separate from a rat its entire digestive system, may form examples of the longer type of Performance Tests.

Performance tests can be very successfully used to assess the ability of the pupils for identification and recognition too. In the first case, they are provided with unknown specimens and the materials needed to test their properties, and they have to identify the specimens. In the second case known specimens are given to pupils. They have to recognise them and write their names.

The pupils may be assessed at the end or at each step, the latter though sometimes difficult being always better.

The performance tests require only little or no verbalisation. This helps to assess understandings that are difficult to verbalise. Similarly this forms the only type of examination by which the laboratory and manipulative skills can be tested. But this

is time-consuming and uneconomical. Similarly, with large groups, the administration of the test becomes difficult.

B. Picture and Diagram Tests

These tests generally take two forms. Sometimes pupils are asked to draw diagrams and pictures and explain things, sometimes they are given pictures and diagrams with accompanying questions.

Pupil's pictures and diagrams reveal their power of observation and depth of understanding. Four points may be borne in mind when we assess the merits of a diagram.[7]

1. Does it represent an apparatus which will serve the purpose required ?
2. Are the parts shown in reasonable proportion ?
3. Is it neatly drawn ?
4. Is it neatly and accurately labelled ?

For the last two a certain minimum standard should be required before any credit whatever is given for the diagram. Marks may be allotted for the above different criteria.

The following are examples of this type of test.

1. Draw a diagram of the common balançe and name its parts.
2. Draw the diagram of three stages in the germination of maize and label parts.

When pupils are provided with pictures and diagrams, they may be asked to identify, label parts, etc. Sometimes incorrect and incomplete pictures are provided and they are asked to correct and complete respectively.

Example :

1. The diagram of an electric bulb, a switch and dry cell may be provided and the students may be asked to make connections so that the bulb gives light when the switch is on.
2. In the laboratory preparation of carbon di-oxide, a diagram may be given as the gas being collected by the downward displacement of air. They may be asked to correct the diagram.

The Diagram Tests have slight advantages over the purely verbal tests. They help better when questions cannot be clearly

formulated by words. They are also of high value when actual specimens are not available or when internal structures are to be tested But pictures and Diagram tests have disadvantages also. They are far removed from reality and for pupils incapable of abstract thinking, difficult to interpret.

C. Verbal Tests

As mentioned earlier, verbal tests can be classified under two broad heads, *oral* and *written*. They measure the factual information that the student has acquired. But to get the best results, the students should be made aware of the nature of questions beforehand. Materials that are not dealt with in the class should not be tested. Again verbal tests have to take for granted four variables which the examiner should not forget. They are :

1. A teacher may not express precisely what he wishes to find out from the pupil.
2. The pupil may not interpret the question correctly.
3. The pupil may not express his knowledge accurately.
4. Finally, the teacher may misinterpret the pupil's answer.[8]

It is thus possible for a pupil to fail a test while possessing the essential information.

(*a*) *Oral tests*

Generally oral tests take the form of interviews. Here the examiner asks certain questions, the answers of which the students have to give. Oral tests are more flexible than other types for the examiner can build upon the answers of the pupils. The pupils also get a chance to explain their answers further and clarify points to the examiner. The accuracy of oral expression of the students can be tested. There is provision for immediate reinforcement by way of correcting the answers then and there. The examiners are liberated from the menace of valuing answer papers. Oral tests cover much more ground than other tests.

The teacher should plan thoroughly and carefully for a successful oral test. He should be full well aware of the objectives of each question. Questions should be worded in simple, clear and unambiguous language. They should be

thought-provoking and must not be either too simple nor too difficult for the pupils to answer. Questions should be asked to assess what they know and not to exhibit their ignorance. Pupils may be given sufficient time to think before they are called upon to answer. The examiners should also establish good rapport with the pupils before the actual oral testing.

(*b*) *Written tests*

The written type of tests are the most popular of all test items. Though they have very severe shortcomings, because of the ease in administration, they have become the favourites of teachers. Written tests require the students to write down something—sometimes very long answers, sometimes comparatively short and sometimes only one or two words or even symbols. The essay, the short explanation and the new objective are the three types of written tests.

1. The Essay Type

This is the most traditional of all written tests. Essay type questions require the students to write out long answers to one question. This gives them training in expression, precise use of words, writing concise and accurate paragraphs, organising knowledge on a particular topic and arrange its several parts in the order of their relative importance, arguing in a logical manner and describing a process with proper attention to the sequence of operations involved. These are skills which are difficult to be tested by other test items.

Essay type questions can be of two types. It may be a single question like 'Describe how a submarine is made to rise or sink', or a group of short questions constituting one essay question like, 'Define photo-synthesis. Describe its chemistry. Arrange an experiment to show that sunlight is quite essential for photo-synthesis'.

The essay type questions have many advantages. They are highly flexible. Many factors can be tested by them like the knowledge in recent and remote facts, useful knowledge—both for the present and future--power of accurate description and correct observation and graphic representation and the

ability to arrange arguments to lead to a generalisation and to apply knowledge gained in new situations.

The main disadvantage of the essay type is in its subjectivity of scoring. As the answers vary widely when valued by different examiners or sometimes when valued by the same examiner on different occasions, the same pupil gets different marks. Essay questions give more importance for factual information and thus indirectly help cramming. Again a scientific diagnosis of the answers is not possible. As there are so many skills necessary in writing an answer, the teacher cannot very easily find out in which aspect the student is poor—in knowledge or memory or ability for generalisation or in expressing the ideas. Similarly long answers are called for each question and this results in much time and energy being wasted in writing answers. The co-ordination of many activities like thinking, organising, writing, etc., causes fatigue in students. Again all portions cannot be covered within a limited time.

The modern trend is to discard the essay type and substitute in its place short essay and objective tests. But the total abandoning of the essay type is most unjustifiable as certain areas can be tested only by them. Saunders ridicules this trend in the following way. "To ask 'which are better, long or short answer questions ?' is to miss the point. They are two tools devised to serve different purposes. A chisel is not better than a saw : each has its proper function. A man who used either chisel or saw for the same job would forfeit any claim to be a skilled carpenter. Similarly a teacher who uses either long or short answer questions for the same task, or who restricts his tests to one type only, equally forfeits any claim to being competent. A well designed examination paper will contain both types of questions."[9]

2. The Short Explanation Type

These are nothing, but miniature forms of essay questions. Whereas the essay type requires long answers, these questions require very short answers, generally one or two sentences but never more than a short paragraph. Definitions, short explanations, citing reasons, etc., can be asked as short answer

questions. They yield better results if only one skill or aspect is tested by one question.

Examples

1. Define catalysis.
2. The lizard can climb even through very polished surfaces. Why ?

Though these tests are not perfectly objective, they can be scored more objectively than the essays. As only one skill is tested, they can be made use of for diagnostic and remedial teaching. Much time can be saved and more portions can be covered.

But they call for highly concise and precise use of words which is very difficult with many children.

3. The New Objective Type Tests

The new type tests have become the fashion of the day. They are the results of attempts made to rectify the defects in the essay and short answer tests. Here questions are so worded that the answers can only be either totally correct or incorrect. They reduce writing to the minimum. The answers are very brief and consist of only a word or phrase to be written or some specified sign to be put or a line to be drawn between two points or sometimes to cross certain words.

These tests can measure not only the scholastic achievements of the pupils, but also their intelligence, aptitude, etc. Because of the objectivity in rating, they can be standardised. They are ideal for diagnostic purposes also, for each item of these tests can be used to measure a specific skill.

The chief merit of the new type test lies in its objectivity of scoring. As answers are either wholly correct or incorrect, even when valued by different examiners the same pupils get the same marks. They are in ample variety. Matching tests, True-false, Association type, Multiple choice, etc., are only few among the various new type tests. If properly constructed, the valuation of answers is no problem. Scoring keys can be used and time can be saved. As a number of questions, all having equal importance, can be asked, the pupils

do not lose much even if they answer wrongly certain questions. There is also wide coverage of portions.

But these tests have certain demerits too. Many factors that can be tested by essay type cannot be tested by them. The power of graphic representation, skills in drawing diagrams and graphs, ability to explain experiments etc. cannot be tested. There is no scope for giving training in the organisation of subject matter, self-expression, etc. New type tests tend to become highly factual, with its corresponding stress on rote memorization. Guessing of answers is possible. Chance plays its part and thus distorts the accuracy of the testing to some degree.

Kinds of New Type Tests

There are a variety of new type tests, like the True-false, Multiple choice, Matching type, etc. For testing any aspect of science like the capacities for reflective thinking and applying scientific principles, testing the scientific attitudes, power of retention and understanding, development of skills, etc., different tests can be constructed. In fact the same type of test, if constructed suitably will measure any of the above aspects. The following are some of the popular new type test items.

A. Matching Type

In these types of tests, the pupils are asked to select and correlate between inventions and inventors or terms and definitions or such other things. This measures the capacity for association or correlation and for establishment of relationships. If on any one side more items are given, guess work can be minimised. Instructions will be given to pupils, to pair the words in the two columns and indicate their decisions by writing letters or numbers in appropriate blanks.

Example

Choose from the list at the right the word that seems most closely related to each of the word in the left hand column. Write the number of words in the corresponding blanks.

(—) Thermometer	1. Reflection
(—) Darwin	2. Cell theory
(—) Mirror	3. Measures relative humidity
(—) Mendel	4. Survival of the fittest
(—) Barometer	5. Laws of heredity
	6. Measures temperature
	7. Refraction
	8. Measures pressure of atmosphere.
	9. Instrument used for magnifying things.
	10. Early Greek botanist.

Too many items will confuse the students. Not more than ten items should be provided at a time. A broad range of materials can be tested by these tests.

B. True-false Tests

Here the pupils are asked to say whether a statement is true or false. They need merely to put some symbols (like, +, —, ×, etc.) or write letters 'T' or 'F', etc., as directed.

Example

Against each of the following statements, put in the space provided 'T' if the statement is true, and 'F' if the statement is false.

1. Filariasis is caused by culex mosquito ( )
2. Coconut oil is denser than water ( )
3. Ice must change into water before it can change to vapour ( )
4. Air is light. Therefore, the more air one pumps into a tyre, the lighter the tyre becomes. ( )
5. Milk is a complete food for babies ( )

This item is good for pretests and for initiating discussions. To avoid merit by guess work, same number of correct items and incorrect items are mixed and presented. Sometimes scoring also is done by the 'Right-Wrong' method.

True-false items are not well suited for determining grades. The material, which on many occasions, lends itself for these types of tests is relatively unimportant in science.

Modified True-false items are used to rectify the defect in this item. Here the pupils are asked to re-write false statements so that they are true. Sometimes a third alternative other than true and false is offered to make it 'sometimes—always—never' test item. This reduces considerably the chances for guess work.

C. Completion Type

The pupils are given a statement that lacks a key word or phrase for complete meaning and are asked to add these missing words. This measures very well the recalling ability of students. But understandings cannot be tested. Moreover mechanical scoring is also difficult. Anyhow too many blanks should not be given.

Examples

Complete the statements by inserting the apt word or words.

1. Lines joining points of equal atmospheric pressure are called.........

2. The part of the automobile engine where air and gasoline vapour are mixed is the.........

3. The......is a wall muscle which separates the......from the abdomen.

4. Butterfly's mouth parts are adapted for........

5. An explosive gas that is lighter than air is.........

D. Multiple Choice Tests

Multiple choice is really another form of the completion type. Here also the statements are not completed. But several possible answers are given and the pupil is to select the correct from them. This stresses more on recognition than on recall. But the construction of such tests must be only very carefully done. There should be only one correct answer. But all should look as possible answers.

Example

Choose from the list of possible answers that which is most correct and write the number in the blank space at the right.

(*a*) Ammonia gas is not collected over water because, (   )

1. It is alkaline gas.

2. It is colourless.
3. It dissolves readily in water.
4. It is lighter than air.

(*b*) The Brownian movement is the motion of small particles of matter caused by, ( )

1. electro statics
2. gravity
3. radio activity
4. molecular action.

(*c*) The main reason for using a wire-gauze in a Davy's safety lamp is that it, ( )

1. is a good covering for the lamp.
2. is a bad conductor of heat.
3. is a good conductor of heat.
4. attracts heat very easily.

(*d*) An example to the Malvaceae family is, ( )

1. Anona
2. Thespesia
3. Cocusnucifera
4. Hibiscus.

E. Best Answer Tests

This is only a kind of multiple choice test. Here all the answers given are correct, but only one is the best and perfect and the pupil will have to choose that. This is more difficult from the pupils point of view for they have to discriminate from closely possible answers.

Example

(*a*) Osmosis is defined as ( )

1. absorption of water by the root hairs.
2. diffusion of particles of a substance through a suitable membrane.
3. a form of diffusion which results in pressure.
4. the process by which plants get their food.

(*b*) A room provided with doors, windows and ventilators is more comfortable than one provided with doors and windows alone because,

1. Cool air can enter the room through the ventilators.

2. Heat and light can enter through the ventilators.

3. Warm air can go out through the ventilators.

4. Warm air gets out and cold air gets in through the ventilators.

F. Analogy Test

This also is only a form of completion test, adapted to test the pupils' ability to see fundamental relationships between various items. They have to think analogically to find the answers. For example, Barometer is to atmospheric pressure as thermometer is to temperature. Here any one word (say barometer, atmospheric pressure, thermometer, or temperature) will be left out and the pupils have to choose. In this case it becomes a combination of completion type and multiple choice.

Example

Fill in the blanks with correct words.

1. Retina is to eye as......is to camera (lens, sensitive plate, cover)

2. Oxygen is to potassium chlorate as carbon dioxide is to......(Calcium carbonate, limewater, carbon).

3. Penicillin is to Fleming as......is to Marconi (Television, Wireless, Photography).

G. Grouping Tests

In these tests, pupils are given a number of items that have something in common among them along with one or two other items, which are in no way related to them. The pupils have to select those that are related in some way and have to discard those that are not. But if more items are given, there are possibilities of alternative groupings.

Example

Cross out the word that does not seem to belong with the others.

1. Elephant, cow, duck, horse, cat.

2. Potassium chlorate, Manganese dioxide, Sulphuric acid, Sodium chloride.

3. Hygrometer, barometer, ammeter, anemometer, thermometer.

H. Arrangement Tests

These tests measure the knowledge of sequence and order. But for grading students this is not a good item, for it becomes difficult to give partial credit. Hence the pupils are given a list of items which they have to arrange in some specified order. Sometimes drawings about the different stages of a process are provided and they are asked to arrange.

Example[10]

Following are the names of planets. List these in the order of their distance from the sun, beginning with the nearest.

Mars	Earth	Uranus
Pluto	Saturn	Jupiter
Mercury	Neptune	Venus

Characteristics of Good Tests

Good tests should have four qualities,

1. Objectivity
2. Validity
3. Reliability
4. Usability

1. *Objectivity* : A test is said to be objective, when scored by equally competent scorers, every pupil gets the same amount of marks. All new type tests are objective in nature. But essay type questions are not objective. Even if the same examiner values the same essay type answer on two different occasions, the marks may vary considerably, not to speak of two different examiners valuing. This is because of the difference in the answers of students and the lack of standardised answers.

2. *Validity* : A test is said to be valid, when it measures accurately what it is supposed to measure. Thus validity means purposiveness. Suppose the test is constructed to measure the subject competence of the students. Then if the test is valid, the students who know the subject matter better should get better scores. Curricular and statistical validity are there. Curricular validity can be ensured by setting questions proportionate to the weights assigned to the various topics. Statistical validity is calculated by comparing the test

scores with the scores of some standardised tests, or the class teachers' ratings. The correlation co-efficient obtained is the index of validity. A validity of 0·8 and above is considered satisfactory.

3. *Reliability* : A test is said to be reliable, when given to the same pupils on two or more occasions, each pupil gets the same marks, allowance being given for slight improvement by practice. A test may be reliable without being valid but cannot be valid without having reliability. The easiest way of finding out the reliability of a test is by the 'test-retest' method. Here the same test is administered to the same set of students on two occasions after an interval of time. The correlation is expressed as stability co-efficient. The 'split-half' method and the method of 'parallel forms' are also used for finding out reliability.

4. *Usability* : Usability is another characteristic of all good tests. It means ease in administration, valuation and interpretation. Detailed directions must be provided both for the administrator and the testee. The test should not cause fatigue in students. It should not be too much of a menace for teachers who have to evaluate and interpret it. For reliable interpretation, the norms of the test should be provided for teachers.

Scoring the Answer Sheets

Objective type questions, if intelligently prepared, can be easily scored. Scoring keys can be constructed which will reduce the time required for valuing an answer book to a few seconds. Any text book on 'evaluation' will give training for teachers in preparing keys.

But essay type questions and some short answer questions evade the use of scoring keys. They are highly subjective and unless proper care is taken to reduce this subjectivity to the minimum, test results won't help any interpretation at all. If the teacher bears in mind the following points, it may make the evaluation of essay type answers more objective.

It is better if the teacher himself has a model answer. Here the essential points for each answer should be arranged

in the order of their importance, and marks should be divided among them as per their weightage. The total marks should also be divided among the various questions according to their importance. (This should be printed in the question itself to make the students also aware of this and this may help them to distribute the total time to various questions according to their weightage.) Value the first question of each pupil, then pass on to the second, third etc. The most important defects should be noted in the answer books for later discussion in the class.

Summary

Evaluation is a term which has broader meaning than 'examination'. It should be a continuous process to effect remedial teaching. Tests are useful in evaluating the children. There are Performance tests, Picture and Diagram tests and verbal tests. Verbal tests can be either oral or written. Essay, short essay and new type constitute the written tests. There are many types of new objective tests. Matching type, True-false, Completion, Multiple choice, Best answer, Analogy, Grouping, Arrangement tests, etc., are some of them. Different kinds of tests can be used to evaluate different aspects of teaching. Anyhow a good test must have four qualities— objectivity, validity, reliability and usability.

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